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## AND ABSTRACT OF THE LITERATURE

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Recent Investigation on Atmospheric Conditions in Industry

The Preparation of Hatters' Fur: A Chemical Study of the Carrotting Process

Miners' Nystagmus from the Point of View of the Workmen's Compensation Act

Observations upon the Effects of Exposure to Arsenic Trichloride upon Health

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# THE JOURNAL OF INDUSTRIAL HYGIENE

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## RECENT INVESTIGATION ON ATMOSPHERIC CONDITIONS IN INDUSTRY*


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DURING the last three years a number of investigations on the atmospheric conditions under which certain industries are carried on have been made at the instance of the Industrial Fatigue Research Board. Their value lies largely in the fact that in all of them great use was made of the kata-thermometer, an instrument invented by Dr. L. E. Hill. This instrument has been described in detail by Orenstein and Ireland in a recent number of THIS JOURNAL (1). For the present purpose it is sufficient to say that it measures the *cooling power* of the air. This cooling power, as measured by the dry kata-thermometer, is dependent on two factors, the dry bulb temperature of the air, and its velocity of movement. By means of a simple formula it is possible to calculate the air velocity in a workshop from the cooling power. The cooling power of the wet kata-thermometer is more complicated, as it depends on the evaporation of moisture from the surface of the kata-thermometer bulb, as well as on temperature and air movement; but it has been shown by Hill, Vernon, and Hargood-Ash (2) that the wet kata cooling power can be calculated approximately from the wet bulb temperature and the air velocity in accordance with these formulae:

For air velocities below 1 meter per second

$$H' = (0.35 + 0.85\sqrt{v})\,\theta'$$

For air velocities above 1 meter per second

$$H' = (0.10 + 1.10\sqrt{v})\,\theta'$$

where $v$ is the air velocity in meters per second, and $\theta'$ is the difference between 36.5°C. and the wet bulb temperature.

These formulae, and the corresponding dry kata formulae which are recorded by Orenstein and Ireland, were determined by two independent methods. In one of them the air movement was effected by drawing air through a "wind tunnel" by means of a propeller. In the other, the kata-thermometer was clamped to a metal rod which was


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revolved in a horizontal plane at a known rate, a correction being applied for the "swirl" set up. The two methods gave quite consistent results.

The adequate investigation of the atmospheric conditions in a workshop is inevitably a laborious process, as it is necessary to make observations, not only at various times during the course of the working day (and working night as well if there is a night shift), but at various times in the course of the year, in order to determine the experience of the workers at the extremes of heat and cold to which they are subjected in the course of their daily round of work. In addition to the observations in the shops themselves, it is very desirable to make extended observations in the air outside the shop, for the importance to be attached to a given kata-thermometer value depends greatly on the outside air conditions at the moment.

The observations to be described may conveniently be divided into two groups, according as they relate (1) to workshops where the nature of the industrial processes carried on does not, or should not, interfere with the atmospheric conditions to such an extent as to prevent the attainment of what is regarded as a normal standard; and (2) to shops where the industrial processes are such that the usual standards have to be relaxed to some extent.

## Workshops with Normal Atmospheric Conditions

At the present stage of our investigations, the word "normal" is necessarily somewhat indefinite, for there is no general agreement as to what constitutes normality. Dr. L. E. Hill considers that the dry kata cooling power ought to be 6 or more, and the wet kata power, 18 or more. These are convenient standards which may be accepted for most purposes; but with high outdoor temperatures some relaxation may be necessary. Such relaxation is most easily determined by considering the temperature and the degree of air movement independently.

Firstly, therefore, we have to decide what constitutes a normal standard of temperature in a well-constructed workshop. An American firm suggested a temperature of 65° to 67° F. in shops where men are moderately active and able to move about, and a temperature of 55° to 65° in foundries, smithshops and carpenters' shops, where active work is the rule. At an English factory the standards suggested were several degrees lower, while Hambly and Bedford (3), as the result of their observations in the boot and shoe trade, suggested a temperature of 60° to 65° for an active operation such as sole-cutting. Vernon and Bedford (4) suggested a similar temperature for potters' shops, where the work is of a continuously active character, though it is not heavy. Such a temperature cannot be maintained in hot weather, but in England outdoor temperatures above 65° are seldom observed, except in the late morning and the afternoon, and as there is always a considerable delay in the transmission of heat from the air outside to the air inside a substantially built factory, it should be possible, as a rule, to keep the factory temperature only slightly above 65° when the outdoor temperature is 65°. At higher outdoor temperatures it is often possible to keep the factory temperature slightly *below* that outside, because of the delay in the transmission of heat. Standards of factory temperature in relation to outdoor temperature are suggested in Table 1.

The reasonableness of these standards is supported by data adduced by Vernon and Bedford, which relate to observations made in a fuse factory. One shop investigated was about 200 feet square, and it was confined to lathe work. The temperature near the center of the shop was taken at three-hour intervals between 9 A. M. and 6 P. M., for several months, and it was found that the average temperature varied only from 61.5° to 65.0° when the outdoor temperature varied from 37° to 57°. At higher outdoor temperatures the shop temperature usually showed a slight excess, and at 62°, 67° and 71°, it was respectively 4.1°, 1.9° and 1.2° greater in the shop; but at 77° it was 1.4° *lower* in the shop than outside. If the cooling power is kept at 6.0 at all temperatures, it follows that the air velocity must range from 14 feet per minute at a factory temperature of 62.5° to 175 feet at a factory temperature of 79°. This latter air velocity would be very difficult to maintain, and it has very seldom been found in the observations hitherto made. Even velocities of 94 to 97 feet, which correspond to a kata value of 5.0 at 79° and to one of 6.0 at 75°, are seldom attained; but the velocity of 47 feet, which is required to give a cooling power of 5.0 at a temperature of 75°, is frequently observed. I suggest, therefore, that Dr. Hill's standard of 6 should apply only to outdoor temperatures of 70° or less, and that at higher temperatures a standard of 5 should suffice, or even less than this at temperatures above 80°. The data obtained in the workshops of various industries will now be discussed in the light of the suggested standards.

TABLE 1.—SUGGESTED STANDARDS OF TEMPERATURE AND COOLING POWER

| Outdoor Temperature | Indoor Temperature | Dry Kata Cooling Power and Corresponding Air Velocity |
|---|---|---|
| ° *F.* | ° *F.* | |
| 60 (or less) | 62.5 (60 to 65) | 6.0= 14 ft.; 7.0=31 ft. |
| 65 | 67.0 | 6.0= 28 ft.; 6.5=40 ft. |
| 70 | 71.0 | 6.0= 42 ft. |
| 75 | 75.0 | 6.0= 94 ft.; 5.0=47 ft. |
| 80 | 79.0 | 6.0=175 ft.; 5.0=97 ft. 4.0=42 ft. |

*The Boot and Shoe Industry.*—This industry was subjected to an extensive examination by Hambly and Bedford (3), who investigated thirty-five factories, situated in seven different counties. They made observations at all times of the year; but for convenience of analysis they divided their results into "winter" and "summer" observations, according as they were made when the outdoor temperature was below or above 50° F. Altogether they made 377 winter observations and 276 summer observations; the frequency of occurrence of the various dry kata cooling powers is recorded (as percentages) in Table 2. Of the winter observations, all but 5 per cent. showed a kata cooling power of 6 or more, and they may therefore be regarded as satisfactory. Of the summer observations, 37 per cent. had a lower cooling power than 6, and 18 per cent. had a cooling power less than 5. To what extent were these low values dependent on high outdoor temperatures? A temperature of 70° or more was observed in only 10 per cent. of the summer observations, and a temperature of 80° was never observed; hence the frequency of occurrence of kata values below 6 was three or four times greater than that permitted by the standards suggested in Table 1. This excess of low values was due partly to the unduly high shop temperatures, and partly to insufficient air movement, as is indicated by the air velocities recorded in Table 3. It will be

seen that 18 per cent. of these observations show less velocity than 25 feet per minute, and 60 per cent. of them less than 41 feet. It is true that 20 per cent. of them showed a velocity of 52 feet and upwards, or sufficient to yield a kata cooling power of 5 at a temperature of 75°, but the high air velocities did not by any means always occur when the shop temperature was high, and accordingly the cooling power observed sometimes fell below 5, and even below 4.

In spite of this criticism, the atmospheric conditions observed in the boot and shoe industry must be regarded as fairly satisfactory, on the whole. The standard of cooling power attained applied almost equally well to all departments of the industry, as the median (or middle) cooling power in each of the six departments investigated was always 7.0 or more in winter, and 6.2 or more in summer. Hambly and Bedford point out, however, that this uniformity in the atmospheric conditions is contrary to the rule that cooling power ought to vary with the character of the work done. For instance, girls engaged in the fairly light sedentary work of boxing and treeing shoes were subject to lower temperatures and higher cooling rates than the men engaged in rather heavy manual work.

*The Printing Trade.*—In the printing works investigated, the atmospheric conditions were not nearly so satisfactory as in the boot and shoe factories. At the request of Dr. Hill, Mr. P. G. Edge made observations in ten printing works, all situated in London, but the majority of the data were collected in three large works. It will be seen from Table 2 that 216 observations were made in winter (January to April), and 66 in summer (June to July). A cooling power of less than 6 was observed in 38 per cent. of the winter observations, and in no less than 91 per cent. of the summer observations. This was due largely to the low air velocities, for it will be seen in Table 3 that the median velocity was only 20 feet per minute in winter, and 18 feet in summer, or not much more than half as great as in the boot and shoe factories.

*The Pottery Industry.*—Observations in the pottery industry were made by Vernon and Bedford (4). They were confined to potters' shops, where the workers are engaged in making plates, cups, saucers and other articles out of moist clay, or china "slip." The articles made are transferred immediately to the potters' drying stoves, usually situated in the middle of the shops, into which they almost invariably pour out large volumes of hot air. For this reason the shops are nearly always overheated, as was proved by making systematic series of observations in winter and in summer. The temperature in the majority of the shops was found to be from 5° to 9° above what is regarded as reasonable, and in some of them the temperature was over 70° F. for the larger part of the year. It might be thought that the passage of heat from the drying stoves to the shop is unavoidable, and that the kata records obtained ought to be discussed in the next section, under the heading of industries with abnormal atmospheric conditions. This is not so, for it has been shown (4) that the outward passage of heat is due to the faulty construction of most of the stoves, but that stoves do exist which retain practically all their heat. They are highly efficient in other ways, and ought certainly to be installed in place of the inefficient stoves now found in most pottery works.

Owing partly to the high shop tem-

peratures, the kata cooling power observed in potters' shops are usually very low. As can be seen from Table 2, 61 per cent. of the winter observations and 89 per cent. of the summer observations fell below 6. The median (or middle) cooling powers came to 5.6 and 4.5, respectively, as compared with values of 7.4 and 6.4 for winter and summer observations in boot and shoe factories. The low cooling power in potters' shops, however, was as much dependent on deficient air movement as on high temperature. In Table 3 it will be seen that the mean velocities in winter and summer were only 17 and 21 feet per minute respectively, or not much more than half those observed in boot and shoe shops. A velocity of 25 feet or more was observed only in 18 to 38 per cent. of the observations made. It might be thought that these low velocities were dependent on some peculiarity in the construction of the potters' shops, but such is not the case. They were due chiefly to the wish of the potters themselves, as was proved

TABLE 2.—FREQUENCY OF OCCURRENCE OF DRY KATA COOLING POWERS

| Dry Kata Cooling Power | Boot and Shoe Shops | | Printing Works | | Potters' Shops | | Cotton Weaving Sheds | |
|---|---|---|---|---|---|---|---|---|
| | Winter | Summer | Winter | Summer | Winter | Summer | Winter | Summer |
| | % | % | % | % | % | % | % | % |
| Below 4.0 | 0 | 8 | 3 | 26 | 3 | 29 | 6 | 28 |
| 4 to 4.9 | 1 | 10 | 5 | 26 | 18 | *34* | *44* | *51* |
| 5 to 5.9 | 4 | 19 | 30 | *39* | *40* | 26 | 36 | 19 |
| 6 to 6.9 | 28 | *28* | *35* | 9 | 24 | 8 | 13 | 2 |
| 7 to 7.9 | *35* | 20 | 22 | 0 | 12 | 2 | 1 | 0 |
| 8 to 8.9 | 18 | 9 | 5 | 0 | 3 | 1 | 0 | 0 |
| 9 or more | 14 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| Median cooling power | 7.4 | 6.4 | 6 2 | 4.8 | 5.6 | 4.5 | 5.0 | 4.3 |
| Total observations | 377 | 276 | 216 | 66 | 289 | 463 | 247 | 187 |

TABLE 3.—FREQUENCY OF OCCURRENCE OF VARIOUS AIR VELOCITIES

| Air Velocity | Boot and Shoe Shops | | Printing Works | | Potters' Shops | |
|---|---|---|---|---|---|---|
| | Winter | Summer | Winter | Summer | Winter | Summer |
| *ft. per min.* | % | % | % | % | % | % |
| Under 10 | 13 | 18 | 1 | 6 | 3 | 4 |
| 10 to 14 | | | 23 | *30* | 28 | 13 |
| 15 to 19 | | | 21 | 17 | *32* | *24* |
| 20 to 24 | | | *25* | 16 | 19 | 21 |
| 25 to 30 | *21* | 15 | 13 | 11 | 13 | 16 |
| 31 to 35 | 17 | 13 | 7 | 9 | 3 | 7 |
| 36 to 40 | 14 | 14 | 2 | 2 | 1 | 6 |
| 41 to 51 | 19 | *20* | 4 | 3 | 1 | 3 |
| 52 to 74 | 9 | 10 | 3 | 4 | 0 | 5 |
| 75 or more | 7 | 10 | 1 | 2 | 0 | 1 |
| Median air velocity | 35 | 37 | 20 | 18 | 17 | 21 |
| Total observations | 373 | 273 | 216 | 66 | 289 | 463 |

TABLE 4.—OPEN WINDOWS AT POTTERS' SHOPS IN RELATION TO TEMPERATURE

| Average Temperature Outdoors | Average temperature in Shop | Percentage of Windows | | | Percentage Window Space Open |
|---|---|---|---|---|---|
| | | Shut | Half Open | Open | |
| ° *F.* | ° *F.* | | | | |
| 36.3 | 66.5 | 88 | 8 | 4 | 8 |
| 46.3 | 69.8 | 78 | 21 | 1 | 11 |
| 55.4 | 72.2 | 48 | 42 | 10 | 31 |
| 65.6 | 76.0 | 19 | 61 | 20 | 51 |
| 73.5 | 80.4 | 10 | 57 | 33 | 62 |

by a very simple method. On every occasion on which we made observations in the shops, we carefully noted the number of windows which were (*a*) closed completely, (*b*) half open, and (*c*) fully open. Most of the windows were of the usual hopper type, which could easily be fixed in any of the positions mentioned, but if any of them were permanently shut up, we ignored them altogether.

In Table 4 are recorded the average results obtained in one of the sets of shops investigated—namely, those provided with "leaf" and "draw-out" stoves. When the outdoor temperature varied from 30° to 39.9° (mean, 36.3°), the shop temperature averaged 66.5°. This was too cold for the potters, for we see that on an average they opened only 4 per cent. of their windows fully, and 8 per cent. of them to half their extent. Roughly speaking, it may be said that the open space is only half as great when the windows are in the half-open position as when they are in the open position, so that in the present instance only 8/2+4=8 per cent. of the total available window space was opened up. At an outdoor temperature of 40° to 49.9° the shop temperature averaged 69.8°, but even this temperature was not considered too hot by the potters, and they opened only 11 per cent. of their window space. At shop temperatures of 72.2°, 76.0° and 80.4° (corresponding to outdoor temperatures of 55.4°, 65.6° and 73.5°), however, they evidently began to think that it was rather too warm, for they opened 31, 51 and 62 per cent., respectively, of their window space. Yet even a shop temperature of 80.4° could not have affected them very much, for they still kept 10 per cent. of their windows entirely shut, and 57 per cent. of them half shut. The probable reason is that they come to the works at the age of 14, and they get so acclimatized to the high temperature that they feel uncomfortable without it. It should be stated that the hopper windows are so constructed that they cause no draft when they are in the half-open position, though they may do so when they are fully opened.

In the shops provided with "dobbin" stoves and "chamber" stoves, the potters did not keep the workrooms quite so warm, but they seemed to prefer a temperature not much below 70°.

The effect of opening the windows was to increase the air currents somewhat, though not as much as might be expected. When the outdoor temperature was at 30° to 50°, the air velocity in the shops averaged 18 feet per minute, while at 50° to 60° it was 21 feet; at 60° to 70°, 24 feet; and at 70° to 80°, 29 feet. The velocity of the outside air at these temperature intervals was 204, 235, 179 and 176 feet, respectively.

It is pointed out by Vernon and Bedford that in considering the *effective* velocity of the air currents impinging on the skin surface of an actively engaged manual worker, an additional factor has to be taken into consideration —namely, the actual body movements made. Supposing that a potter, who is working in an air current of 20 feet per minute, has to move his body at an average rate of 30 feet per minute in order to carry out his industrial operation, it follows that the effective air velocity, so far as he is concerned, is somewhere between 10 feet per minute (when he is moving in the direction of the air current) and 50 feet (when he is moving against it), instead of 20 feet. As his movements are made at an irregular rate, and as the air current is probably variable in direction and

strength, it is impossible to fix the effective velocity closely, but perhaps it is, in most potters, about midway between the extreme possible limits.

The cooling effect of moving air operates chiefly on the face and head, for the rest of the body, with the exception of the forearms, is normally covered with clothes. Hence the observations made related to the *head movements* of the workers, rather than to the body movements. The method of procedure was a rough and ready one, but it gave consistent results, and was less difficult to carry out than a more accurate method would have been. If, for example, the movements of a man engaged in making plates on a jolly (a rapidly revolving wheel) were under investigation, a few rough measurements of the range of his chief movements were first made with a 2-foot rule, which the observer held in one hand. In the other hand he carried a stop watch. On starting the watch he estimated by eye (giving an occasional glance at the 2-foot rule to serve as a standard) the number of feet through which the potter moved his head. After two minutes the watch was stopped, and the number of feet moved in a minute was calculated. Each investigator made two or more sets of observations on each worker, and took a mean. A sample series, made upon plate makers, will show the kind of consistency attained. The observations in italics were made by one investigator, and those in plain figures, by the other.

*Head Movements of Plate Makers*

| | Ft. per Min. | | | | Mean | |
|---|---|---|---|---|---|---|
| Male No. 1 | *28* | *24* | 30 | 29 | =28 | 30 ft. per min. |
| Male No. 2 | *32* | *34* | 26 | 25 | 24=28 | |
| Male No. 3 | *28* | *27* | 30 | 29 | =29 | |
| Female No. 1 | 32 | 37 | 32 | | =34 | |

It will be seen that the men showed almost exactly the same extent of head movement, while the woman moved rather more than they. The individual workers were usually fairly consistent, but not always. For instance, four saucer makers in one shop showed head movements of 40, 43, 43 and 45 feet, respectively, while a fifth moved only 29 feet per minute.

A large number of observations were made on various classes of workers, and it was found that in most of them the head movements amounted to 20 or 30 feet per minute. On the other hand the mould runners, who have to carry the ware to and fro between the potters and the drying stoves, averaged 70 feet per minute.

## Workshops with Abnormal Atmospheric Conditions

In several of the industries investigated, the nature of the industrial operations is such as to necessitate some departure from normal atmospheric conditions. Especially is this so in certain textile processes, such as the weaving of cotton and linen goods, for with many classes of material it is important to have a hot and humid atmosphere; otherwise breakages of the yarn are much more frequent, and the quality and quantity of the material woven are depreciated. The need for hot and humid air is recognized by the Factory Acts, for the regulations allow artificial humidification in cotton cloth factories so long as the wet bulb temperature does not exceed 75°, and so long as there is a difference of at least 2° between the wet and dry bulb temperatures at 70°, a difference of 3.5° at 75°, and one of 5° at 80° (dry bulb). In flax spinning, linen weaving, and worsted spinning, even more trying conditions are permitted, as a difference of only 2° between wet and

dry bulb temperatures is required, whatever the temperature. It is true that the manufacturers seldom avail themselves of the extreme latitude allowed by law, but observations made in 140 flax spinning rooms in Irish mills showed an average dry bulb temperature of 80.3°, and a wet bulb temperature of 75° (5).

*Cotton Weaving.*—If the temperature of a shed or mill is systematically kept at a high level, it is obvious that the cooling power of the air must be greatly reduced, unless the amount of air movement is correspondingly increased. Hence kata-thermometer observations are particularly important. A large number of observations have recently been made by Wyatt (6), relating to cotton weaving sheds, and the principal results obtained are summarized in Tables 5 and 2. Seven large sheds were tested in winter, and seven in summer, about thirty observations being made at each season in each shed. It will be seen that the dry cooling power averaged 5.2 in winter, and 4.3 in summer, except in one shed. In this the air was not artificially humidified as it was in the others, and a cooling power of 5.0 was observed. The deficient cooling power of the sheds is chiefly due to the high temperatures, for the air currents had an average velocity of 26 feet per minute, which is more than that observed in potters' shops and printing works, though less than that in boot and shoe shops. The wet kata cooling power was even more deficient than the dry kata power, owing to the humidity of the atmosphere. We see that it averaged only 14.9 in the winter and 13.3 in the summer, except in the unhumidified shed, where it showed the nearly normal value of 17.3.

The frequency distribution of the dry kata cooling powers is recorded in Table 2. It will be seen that in winter time half of all the values were below 5, and in summer time, 28 per cent. of them were below 4. Only 14 per cent. of the winter observations and 2 per cent. of the summer observations reached a value of 6.

The extremely deficient cooling power of the air in the weaving sheds during the summer months caused many complaints among the weavers, and there can be no doubt that they were fully justified in making them. Even if the exigencies of the industrial operations required a hot and humid atmosphere, this was no excuse for the low air velocities. By means of suitable ventilating fans they could have been greatly increased. Wyatt has suggested another and very ingenious method of attaining the same end. He found that the air movement in the vicinity of the weaver could be much increased by fastening strips of material of various widths to the loom. The most satisfactory method consisted in attaching the ends of a stiff canvas, 3 inches wide, to the two metal supports on the heald roller. A horizontal board was used to deflect the air toward the weaver, and in consequence the cooling power of the air was raised from 4.6 to 9.0, corresponding to an increase in air velocity from 21 feet per minute to 252 feet.

*Laundry Trade.*—In addition to the textile industries, where a high temperature is desirable in the interests of production, there are other industries in which it can scarcely be avoided, because of the heat incidental to the carrying out of certain of the processes. This is certainly true of laundry work, according to the observations of Miss Smith (7). A large modern laundry was investigated for a week in summer and in winter, the observations being usually made at hourly intervals during the

course of the working day. The extreme variations in the mean dry bulb temperature, the mean dry kata cooling power and the air velocity, calculated from these observations, are recorded in Table 6. It will be seen that in November the cooling power did not fall below 4.5 in any of the rooms investigated, though the temperature rose as high as 80°. This was owing to the considerable degree of air movement, which was induced largely by ventilating fans. The summer observations were made during hot weather, and in consequence the temperature in the laundry rooms was often over 80°, and sometimes over 90°. The cooling power fell to less than 3 in four of the five rooms investigated, in spite of the fact that there was usually a fair amount of air movement, and occasionally a considerable amount.

Observations lasting one or more days were made in the hand-ironing and calender rooms of ten other laundries. In only three of the hand-ironing rooms, and one of the calender rooms, did the cooling power reach the standard value of 6, and in several of the rooms it never rose much above 3, while it fell to less than 2 in the course of the day. This was chiefly due to the high temperatures, as the degree of air movement was usually fairly good. Still, it was by no means sufficient, considering the high temperatures, and if these high temperatures are really unavoidable, they must be compensated for by greatly increased artificial ventilation.

TABLE 5.—MEAN ATMOSPHERIC CONDITIONS IN COTTON WEAVING SHEDS

| Sheds Investigated | Number of Operatives | Number of Observations | Dry Bulb Temp. | Wet Bulb Temp. | Dry Kata | Air Velocity | Wet Kata |
|---|---|---|---|---|---|---|---|
| | | | ° *F.* | ° *F.* | | *ft. per min.* | |
| 7 humidified sheds in winter | 278 | 35 | 70.7 | 65.9 | 5.2 | 26 | 14.9 |
| 6 humidified sheds in summer | 278 | 27 | 74.7 | 70.0 | 4.3 | 26 | 13.3 |
| 1 unhumidified shed in summer | 260 | 24 | 72.1 | 62.8 | 5.0 | 28 | 17.3 |

TABLE 6.—DIURNAL VARIATIONS IN ATMOSPHERIC CONDITIONS AT LAUNDRY

| Place Investigated | Observations in November | | | Observations in August and September | | |
|---|---|---|---|---|---|---|
| | Dry Bulb Temp. | Dry Kata | Air Velocity | Dry Bulb Temp. | Dry Kata | Air Velocity |
| | ° *F.* | | *ft. per min.* | ° *F.* | | *ft. per min.* |
| At folding table | 68.5 to 75.2 | 7.5 to 4.8 | 43 to 94 | 66.0 to 79.5 | 8.6 to 4.3 | 66 to 113 |
| At ironing table | 72.0 to 76.0 | 6.0 to 4.6 | 35 to 71 | 73.0 to 84.9 | 5.8 to 2.4 | 24 to 81 |
| Press room | 73.0 to 80.0 | 6.8 to 4.5 | 82 to 141 | 73.9 to 93.0 | 6.4 to 1.3 | 52 to 120 |
| Calender room | — | — | — | 69.0 to 83.0 | 6.4 to 2.6 | 8 to 52 |
| Collar packing room | — | — | — | 70.0 to 86.0 | 5.4 to 2.5 | 28 to 56 |
| Air outside (at noon) | 56.5 | 16.2 | 289 | 76.7 | 6.8 | 181 |

## Conclusion

Probably it will be admitted that the observations described, though they relate to comparatively few industries, are sufficient to indicate the value of the kata-thermometer in industry. It is evident that systematic investigations ought to be made in all our chief industries, in order that it may be possible to estimate and compare the atmospheric conditions to which the various classes of workers are subjected. If the conditions observed are expressed in terms of temperature and air velocity as well as in cooling power, it will be possible to see at a glance in what direction improvements of the conditions ought to be attempted. It will no longer be

sufficient for a manufacturer to explain that his industrial process requires a high temperature or a humid atmosphere, if we find that he is making no attempt to counteract these requirements by the establishment of greater air movement. Again, if we find that in some of the workshops of an industry the atmospheric conditions are reasonable, and are effected without loss of efficiency, we shall be justified in expecting other and less satisfactory workshops to conform to similar standards.

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# THE PREPARATION OF HATTERS' FUR: A CHEMICAL STUDY OF THE CARROTTING PROCESS*

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THE process of preparing fur for felting purposes by treatment with a mercurial solution has been common practice for a great many years, and dates back to the beginning of the seventeenth century in France. In early times the procedure was kept strictly secret and it was given the name *sécrétage*. During the eighteenth century the knowledge was carried to England and the secret was communicated to a number of workmen, who gradually passed it on. In England and America the process of *sécrétage* is called carrotting, and the solution used for this purpose is known as the carrotting solution, or simply the carrot.

Despite its highly poisonous character, mercury continues to be used for this purpose, and clinical records show a large number of cases of chronic mercurialism among workers in the felt hat industry. Efforts have been made to substitute a non-poisonous metal for mercury but they have not met with success. The present investigation was undertaken with the idea of studying the carrotting process and attempting to replace mercury by an innocuous substance.

To indicate the rôle of carrotting in the preparation of felt hats, the following brief summary will suffice:

*Preparation of the Carrot.*—Although there is variation among hatters' furriers, the ordinary carrotting solution is essentially made by dissolving one part of mercury in five parts of strong nitric acid, and diluting the resulting solution to the desired specific gravity, 10° to 13°Bé. In dissolving the mercury, large quantities of oxides of nitrogen are evolved, and precautions must be taken to prevent the escape of these gases into the working rooms. It is stated in the French literature that the solution for white carrotting is made in the proportion of one part of mercury to three of nitric acid, but this modification is not commonly used in America.

*Preparation of the Hat-Bodies.*—The skins of rabbit, hare, and nutria are opened, shaken out, and brushed, in order to remove dirt and loose hair; the long hairs are then removed by plucking, leaving the short soft hairs, called the fur. The brushed fur is treated with the carrot, which is applied by means of a stiff brush, manipulated by hand or by machine. The excess of the solution is drained away and the pelts are then dried. The drying may take place at a high temperature (120° to 150°C.); or at a low temperature (30°C.), by circulating a current of warm dry air over the pelts. In the first case the drying is complete in less than one half-hour, but the fur becomes yellow in color owing to the action of the hot nitric acid. This quick method, known as yellow carrotting, is very extensively used in America. The second method, called white carrotting, requires a much longer time, but in this case no discoloration is observed. After they are dry, the pelts are again brushed to remove dirt and loose hairs. The brushed pelts are then fed into the cutting machine, where the fur is removed in such a way that it retains its original form. The skin, which is completely shredded, is collected and sent to glue factories. The cut fur is kept in bags until used, and may be stored thus for an indefinite period.

The cut fur is fed into the blowing machine, in which it is picked apart and tossed about in a current of warm air in order to remove dirt, and to separate the coarse hairs and matted parts. The blown fur is weighed and fed into the forming machine in which, by suction, it is drawn against a revolving copper cone. This cone is perforated and measures 27 by 29 inches. The cone, covered with fur,

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is removed from the machine and wrapped loosely in a wet cloth. The whole is then immersed in water for a short while, and the cover cloth and formed hat are removed from the cone. The loose felt is subjected to the forming and sizing process, in which it is alternately immersed in hot water, and kneaded on a wooden plank. The felt thus becomes more compact, and is shrunk to the desired size. The subsequent steps differ with the kind of hat which is to be made, but as far as carrotting is concerned, the finishing processes need not be considered.

The aim of the present work is to study the carrotting process, and to find some non-toxic material which will produce the same effect as mercury. A number of salts of the common metals have been tried as carrots, but the felt produced in this way was always greatly inferior to the control mercury-carrotted specimen. The data and list of solutions used are shown in Table 1.

The change which is brought about during the carrotting process is quite essential for the successful felting and shrinking of the fur, and this has been the subject of numerous investigations. The very first workers noted a change in the appearance of the hair after carrotting. Examined under a microscope, the natural hair appears smooth in outline; after carrotting, the epidermal layer of cells is opened out and the edge of the hair appears rugged like the teeth of a saw. The difference is illustrated in Figures 1 and 2.

It is to this slight change that the beneficial action of the carrot is attributed. According to Sabouraud, quoted by Chaplet, "the effect of 'sécrétage' is primarily to soften and render supple the keratin which forms the sheath of the hair; secondly, to loosen slightly the cortical cells, which are tightly fitted together, in such a way that they remain in place but can be dissociated much more readily by crushing; and finally, in certain cases, to modify the color by acting on the hair pigments."

Hillairet concludes from his work that the interlacing during felting is not due to the development of epithelial inequalities, but chiefly to the extreme flexibility of the fibers after the destruction of their sheath. The subsequent immersion in hot water, and the resulting tendency to twist, assist considerably in the intrication of the fibers under the influence of pressure. This explanation appears to be satisfactory, and has been generally accepted.

In addition to this change, carrotting gives the fur an added weight, which makes the blowing process much more effective. Whereas it is very difficult to blow untreated fur, the added weight of the carrotted fur is an advantage at this point. There is little doubt that any metallic salt which produced a satisfactory carrot, would give the same effect in blowing, for the latter is purely mechanical.

The chemistry of carrotting has been investigated by several French workers, and a number of ideas have been given concerning the "active principle" of the mercury carrot. Hillairet regards the mercury as superfluous and attributes the action solely to nitrated and nitrosated compounds formed by the action of nitric acid and of the nitrous acid which is liberated in a nascent state in the presence of the organic matter. Others have suggested that the mercuric nitrate penetrates into the hair and simply prevents the acid from acting too vigorously. It is certain that nitric acid alone, or with certain other metallic nitrates, when applied in the usual way fails to give a satisfactory carrot, since the resulting felt is inferior in quality (Table 1).

Nitrous acid appears to be an important factor in the process and may originate in two ways: (1) Undoubtedly considerable quantities of mercuric nitrite are formed by the solution of mercury in strong nitric acid; (2) large quantities of nascent nitrous acid are formed by the action of nitric acid on organic matter. It is not unlikely that mercuric salts catalyze the decomposition of nitric acid in the presence of organic matter, and in this way facilitate the formation of nitrous acid.

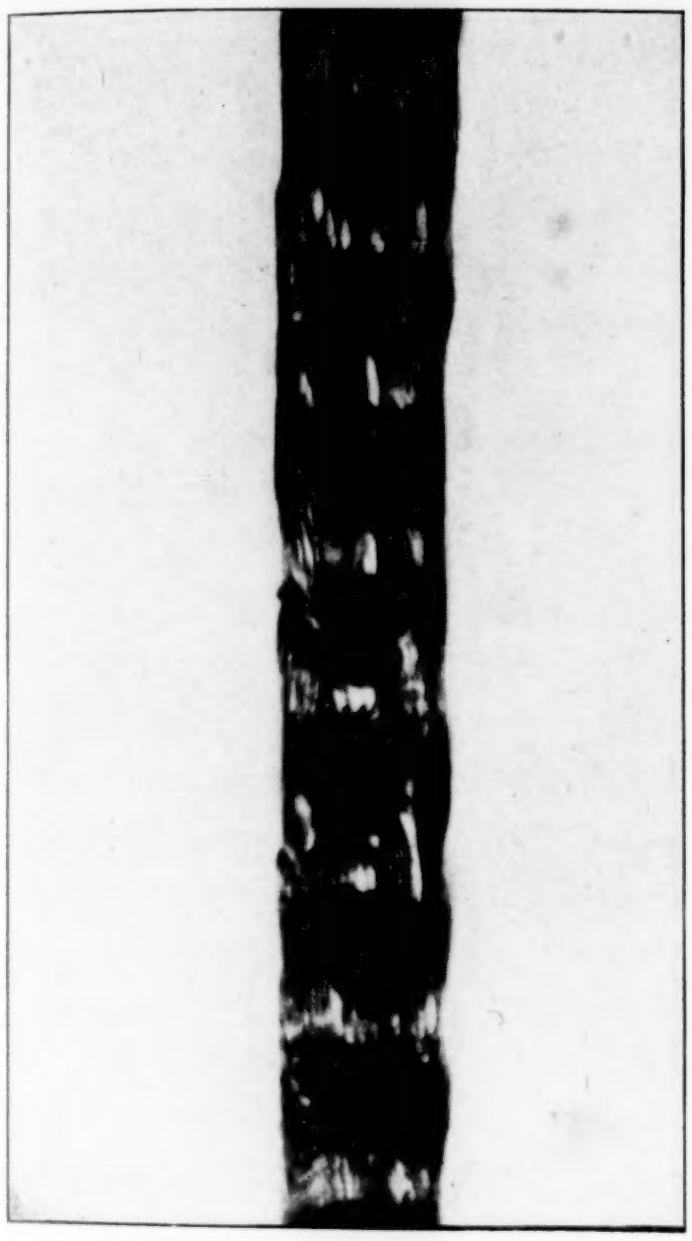

FIG. 1.—Natural hair x 1350.

FIG. 2.—Mercury-carrotted hair x 1350.

## RÉSUMÉ OF PREVIOUS WORK

*France.*—More than one hundred years ago attempts were made in France to find a suitable non-mercury carrot. As early as 1817, Guichardière presented before the Société d'Encouragement des Poils Secrétés sans Mercure a method using sulphuric acid. In the same year, Malard and Desfosses were granted a patent for the use of an alkaline carrot containing two parts of soda to one of quicklime. Bredut (1), who directed the practical tests, stated that the "forming" of fur carrotted in this way was exceedingly slow, and the results were very irregular.

In 1869 Hillairet (2) proposed a non-mercury carrot based on his idea that mercury was not essential, and that the products of the decomposition of nitric acid were sufficient. As an organic substance to facilitate the decomposition he employed sugar or starch[1], or, on a

[1] The procedure of Hillairet is practically the same as that given in a communication from J. L. Roessler in Paris, which was patented in England by J. H. Johnson, in 1867. This patent "consists in substituting for the preparation of mercury, carbohydrates, or other substances capable of decomposing nitric acid into nitrous acid; *e.g.*, raw or refined sugar, gum, and starch."

larger scale, molasses, since it was cheaper.

According to this procedure two solutions are prepared: A, containing molasses; B, containing nitric acid.

*White Carrot*

| | | Kg. |
|---|---|---|
| A. | Molasses | 8.5 |
| | Water | 14.0 |
| B. | Nitric Acid (38° Bé.) | 12.0 |
| | Water | 12.0 |

*Yellow Carrot*

| | | Kg. |
|---|---|---|
| A. | Molasses | 8.0 |
| | Water | 19.0 |
| B. | Nitric Acid (38° Bé.) | 16.4 |
| | Water | 16.0 |

Solution A is applied first, followed immediately by B, and the pelts are dried in the usual manner. When dry the excess of molasses is removed by washing with water, and after brushing, the pelts are allowed to dry very slowly. After this the normal procedure is followed, and according to the literature a very good felt results. Even though a good felt were obtained (which seems doubtful), this modification would not meet with success on account of the increased amount of labor necessary.

In 1884 Grossot (3) patented the use of a mixture containing creosote oil, alcohol, water, and nitric acid. In 1887 Dargelos (4) patented the use of cold dilute aqua regia, containing one part of nitric acid to three parts of hydrochloric acid. In 1890 Fabre (5) patented the use of a mixture of turmeric, alum, salt, and sulphuric acid.

In 1891 Burg (6) obtained two patents including more than ten different carrots. In the latter are included nitric, sulphuric, oxalic, and acetic acids, and the nitrates or sulphates of potassium, zinc, ammonium, copper, iron, antimony, sodium, tin, and aluminum.

In 1892 to 1893 Lussigny (7) patented a white carrot consisting of a caustic alkali, and a yellow carrot consisting of carbon and nitric acid. A dilute solution of potassium hydroxide, it is stated, gave the best results, and is said to have been employed with favorable results by a French manufacturer. The latter failed in 1897, on account of the fact that other firms discredited his product. It is stated by Levitzky (8) that the procedure of Lussigny was used with success in Moscow, and by 1907 was being employed in a large number of Russian workshops. A good account of the French attitude and a summary of previous work is found in Chaplet's article (9).

At the International Congress of Hat Workers in 1907, the procedure of Ronjat (10) was received with great favor. This consists in the substitution of nitrates of tin for mercuric nitrate, with or without the addition of sodium nitrite. The statements of Ronjat (quoted by Martial, 11) seem rational and logical, apparently representing the best work that has been done on the subject. The result of a single trial of tin is reported in Table 1, and although a poor felt was obtained, this was not taken too seriously since it must be remembered that each step in the felting process, as now carried out, has been designed to give the best result with a mercury carrot, and undoubtedly modifications will be necessary to suit a change in the carrot.

*England.*—A number of patents have been granted in England for non-mercury carrotting solutions, but these have been chiefly of French origin. At the International Congress in 1912 Tylecote (12), in a report on mercurial poisoning, referred to the modifications of Hardcastle, using the nitrates of iron and zinc, zinc chloride, and nitrous acid. In the same year Lloyd and Gardner (13)

reported a number of analyses showing the mercury content of hats, hat-bodies, and fur at various stages in the process of hat making.

In 1914 a patent was granted to L. F. Paris (14) for the use of sodium nitrite, sodium hypochlorite, zinc chloride, and nitric and hydrochloric acids. This combination of many active substances is certainly too destructive to be used in the ordinary manner, and no report of its use has been found further than the claims in the patent itself.

*United States.*—Although little work on non-mercury carrots has been published in America, a great many clinical investigations of mercurial poisoning have been made. The first comprehensive work was that of Dennis in 1878 (15). The report of Mrs. Linden W. Bates (16), and that of Louis Harris (17), are regarded as the best in recent years.

In 1917 Braun (18) patented a method consisting in the use of a hot aqueous solution of sodium carbonate. The patent claims that cut fur can be used, and that the hides can therefore be saved and used as cheap leather. In the ordinary procedure the hides are completely shredded and can be used only for the preparation of glue. Although very definite directions are given in this patent, the results claimed could not be duplicated in a large series of trial experiments. Several variations were attempted using sodium carbonate, and soda-ash, but the results were never satisfactory.

## Experimental Work

There were two problems to be considered in connection with this series of experiments: first, the selection of chemical reagents to be used; and second, the choice of a suitable standard for comparison. In selecting the substances to be tried as mercury substitutes, several courses were followed: An attempt was made to replace mercury by another substance which would act in the same manner; solutions recorded in the patent literature were duplicated; and new combinations were tried, either at hazard, or in accordance with theories of the mechanism of carrotting.

Assuming that mercury dissolves in nitric acid according to the equation,

$$3Hg+8HNO_3=3Hg(NO_3)_2+4H_2O+2NO,$$

the ordinary mercury carrot prepared by dissolving one part of mercury in five parts of nitric acid (40°Bé.) would contain one gram-equivalent of mercuric nitrate (162 gm.) to three and one-half equivalents of nitric acid. In a series of tests using other metallic nitrates with nitric acid, the ratio of one equivalent of metallic salt to three and one-half equivalents of nitric acid was preserved, in order to vary the nature of the carrot as little as possible. In actual practice the mercury carrot is diluted to a specific gravity of 12° to 13° Bé. (1.090 to 1.098), and in accordance with this procedure the test solutions were in most cases diluted to 13°Bé.

In selecting the metal nitrates to be used in replacing mercuric nitrate, the Mendeléeff periodic system was found useful, since in this table the elements with similar properties occur in the same groups. From this, zinc and cadmium seemed promising, but the actual results with these metals were discouraging. Using the horizontal series as a guide, lead and bismuth were suggested, but unsatisfactory results were also obtained with these nitrates. Although the felt obtained by substituting lead was of an inferior quality, it was judged as the

best of the non-mercury carrotted specimens. This is rather unfortunate since the poisonous character of lead salts precludes any attempt to perfect a lead carrot.

In addition to the nitrates of the metals already mentioned, salts of a number of common metals were tried out on a small scale in the laboratory, and a few on a larger scale in the factory of the John B. Stetson Company of Philadelphia.[2] The results of these tests are shown in Table 1.

One of the most important considerations in carrying out this series of experiments was the choice of a suitable standard, since no simple comparative method was available. The ideal way would be to carrot the pelts with an experimental solution, convert them into felt in the usual manner, and compare the experimental felt with a control mercury-carrotted specimen. The objection to this method is the expense involved, since the ordinary blowing machine cannot be successfully operated for a charge of less than 1½ to 2 pounds of fur, representing from fifty to sixty pelts. It was therefore advisable to find a means of making preliminary tests and of reserving the large scale tests for a small number of the more promising solutions.

As a preliminary method, the microscopic examination of the dry hairs affords an easy means of following the experiments, but in general the results are not reliable, because the changes are slight and the difference between individual hairs is great. Since the indications obtained by this method were not in good agreement with those obtained by the first method, the results of the actual felting were accepted as final, and the microscopic examination was used merely as a preliminary step.

[2] The writer wishes to acknowledge his indebtedness to the John B. Stetson Company for its cooperation in carrying out a number of practical tests. They were kind enough to place at his disposal the records of their experiments, and to assist and advise in many ways.

### *Technic and Experimental Results*

The series of experiments was divided into two groups: one, executed in the plant of the Stetson Company; and another, carried out on a laboratory scale at the Harvard Medical School. In the first case the trial carrotting solution was substituted for the mercury carrot in the ordinary routine, and the whole procedure was completed in the usual way. The behavior of the trial specimens was carefully recorded and compared with that of mercury carrotted fur. In Table 1, the behavior during shrinking, the time of shrinking, and the quality of the felt obtained from a series of experiments, are recorded.

TABLE 1.—RESULTS OF EXPERIMENTS WITH VARIOUS TEST SOLUTIONS*

| Test Solution | Yellow Carrot | | | White Carrot | | |
|---|---|---|---|---|---|---|
| | Shrinking | Time | Felt | Shrinking | Time | Felt |
| | | *hours* | | | *hours* | |
| 1 | slow | 2 1-2 | fair | fair | 2 | fair |
| 2 | slow | 2 1-4 | poor | very slow | 3 | very poor |
| 3 | fair | 2 | fair | fair | 2 | fair |
| 4 | fair | 2 | fair | fair | 2 1-4 | fair |
| 5 | fair | 2 1-4 | fair | slow | 2 1-2 | poor |
| 6 | fair | 2 | fair | fair | 2 1-6 | poor |
| 7 | fair | 2 | fair | slow | 2 1-4 | poor |
| 8 | very slow | 3 | poor | very slow | 2 5-6 | poor |
| 9 | fair | 2 | fair | fair | 2 | poor |
| 10 | good | 1 3-4 | good | fair | 2 | fair |
| 11 | very good | 1 1-2 | very good | very good | 1 2-3 | very good |
| 12 | good | 2 | fair | impossible | — | — |
| 13 | fair | 2h. 5m. | poor | poor | 2 5-6 | fair |
| 14 | fair | 2h. 5m. | good | fair | 2 3-4 | good |

*In the comments made by the Stetson Company, the standard for comparison is the mercurial carrot in ordinary use in that factory. The time required for shrinking with this carrot is between one hour and thirty minutes and one hour and forty minutes. They considered that solution No. 14—namely, copper dissolved in nitric acid, and

Preparation of the Test Solutions

1. One part of lead was dissolved in four parts of nitric acid (40°Bé.) previously diluted with water, and the resulting solution diluted to 13°Bé.
2. One part of zinc was dissolved in six parts of nitric acid (40°Bé.) previously diluted with water, and the resulting solution diluted to 13°Bé.
3. One part of zinc was dissolved in twelve parts of nitric acid (40°Bé.) previously diluted with water, and the resulting solution diluted to 13°Bé.
4. One part of tin was treated with four parts of nitric acid (40°Bé.) previously diluted with water, and the resulting mixture, which contained a white precipitate of meta-stannic acid, was diluted to 13°Bé.
5. Two parts of potassium permanganate were dissolved in thirty-eight parts of water, and one part of nitric acid (40°Bé.) and one part of concentrated sulphuric acid were added. The resulting solution had a specific gravity of 11.5°Bé.
6. One part of cupric nitrate crystals ($Cu(NO_3)_2.3H_2O$) was dissolved in water, and three parts of nitric acid (40°Bé.) were added. The resulting solution was diluted to 13°Bé.
7. Three parts of cadmium nitrate crystals ($Cd(NO_3)_2.4H_2O$) were dissolved in water, and seven parts of nitric acid (40°Bé.) were added. The resulting solution was diluted to 13°Bé.
8. One part of soda-ash was dissolved in eighty parts of water.
9. Pure nitric acid was diluted to a specific gravity of 13°Bé.
10. One part of mercury was dissolved in ten parts of nitric acid (40°Bé.), and the resulting solution diluted to 13°Bé.
11. Control experiment: One part of mercury was dissolved in five parts of nitric acid (40°Bé.), and the resulting solution diluted to 13°Bé. This is the ordinary mercury carrot.
12. Four parts of bismuth subnitrate were dissolved in nine parts of nitric acid (40° Bé.), and the resulting solution diluted to a specific gravity of 13°Bé.
13. One part of cobalt carbonate was dissolved in three parts of nitric acid (40°Bé.), and the resulting solution diluted to a specific gravity of 13°Bé.

zinc oxide dissolved in nitric acid—gave the best results in both yellow and white carrot, results promising enough to warrant further experimentation but not equal to the results obtained with ordinary mercurial carrot.

14. One part of copper and one part of zinc were dissolved in eleven parts of nitric acid (40°Bé.), and the resulting solution diluted to 13°Bé.

Several experiments were made using the sodium carbonate procedure patented by Braun (18), but no successful results were obtained. In these experiments, cut fur was treated with hot aqueous sodium carbonate solution for definite periods of time (thirty to forty-five minutes), centrifuged to remove excess of the carrot, formed, and hardened in the usual way. In general the shrinking was very slow and the felt poor. A similar experiment with the regular mercury carrot applied to cut fur, gave a very poor felt.

On a small scale, the following technic was employed: The brushed skins, which had been crudely clipped by hand, were impregnated with a test solution by means of a small brush, and dried in a small gas oven at temperatures varying from 40° to 120°C. After they were dry, the skins were brushed and allowed to stand at room temperature for several days.[3] Specimens of fur were then cut from the back and sides and examined under high magnification. For comparison, natural hair and mercury-carrotted specimens were used. By this method the carrots could merely be arranged into large groups; there was no accurate means of distinguishing between individuals within the groups.

To denote the various types of results, four groups were made, corresponding to the brief descriptions: (1) good; (2) fair; (3) fair to poor; (4) poor. These terms are indefinite, but the inaccuracy of the method does not permit any more definite statements.

[3] In actual factory manipulation, carrotted pelts are usually stored at least three months before the fur is cut.

FIG. 3.—Natural hair.

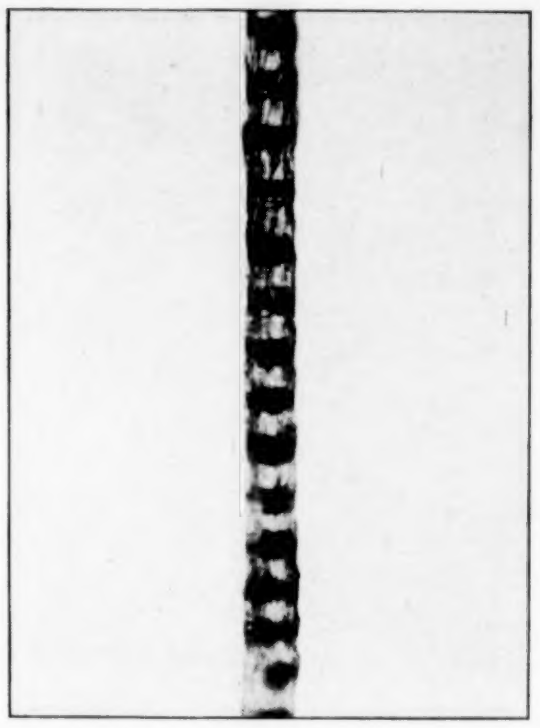

FIG. 4.—Tin-carrotted hair.

FIG. 5.—Cadmium-carrotted hair.

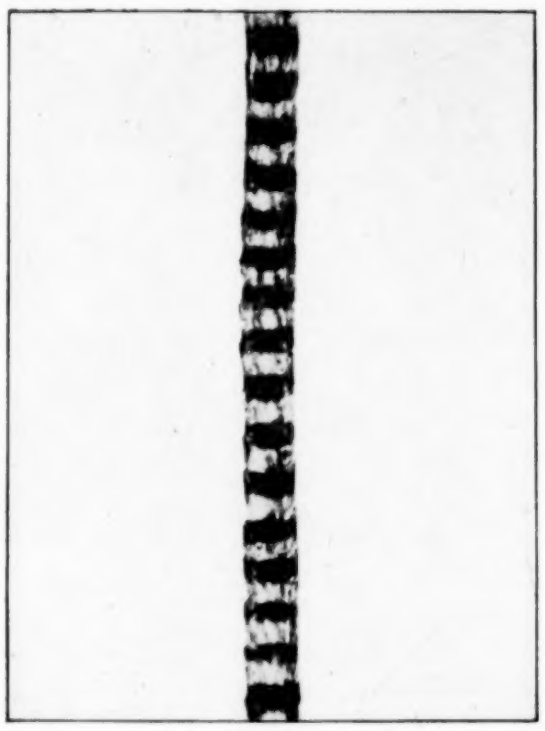

FIG. 6.—Silver-carrotted hair.

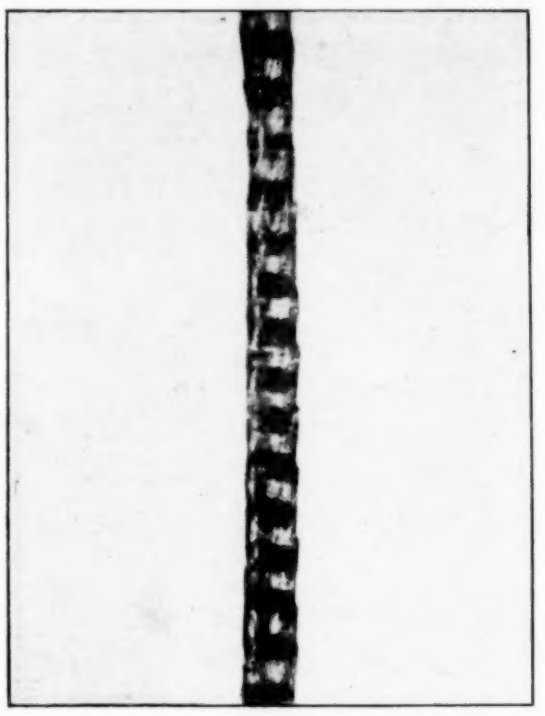

FIG. 7.—Copper-carrotted hair.

FIG. 8.—Mercury-carrotted hair.

*Group 1.*—Mercuric nitrate with nitric acid (control).

*Group 2.*—Nitrate of silver, copper, cadmium, lead, bismuth, cobalt, zinc, nickel, or aluminum with nitric acid.

Cupric chloride and formic acid.

Zinc and potassium sulphates with sulphuric acid (white carrot).

*Group 3.*—Stannic chloride with nitric acid.

Nitrate of iron, sodium, or calcium with nitric acid.

Nitric acid alone.

Sulphate of copper, cobalt, aluminum or manganese with sulphuric acid.

Sulphate or chloride of cobalt, copper, or manganese with hydrochloric acid.

*Group 4.*—Hillairet's procedure.

Mercuric chloride with hydrochloric acid.

Hydrogen peroxide, 3 per cent. solution.

Dargelos' procedure (dilute aqua regia).

Antimony sulphate and sulphuric acid.

Sulphuric, hydrochloric, formic or acetic acid, alone.

Potassium hydroxide.

Sodium carbonate.

Sodium stannite.

In certain cases photomicrographs were made of the specimens, and were found to be very useful for comparing results. The accompanying plates (Figs. 3-8) show a series of photographs of fur from four typical experiments, with photographs of natural hair and mercury-carrotted hair for comparison. In these experiments the ratio of one gram-

equivalent of metallic nitrate to three and one-half equivalents of nitric acid was used, and the yellow-carrotting procedure was followed.

The results of the experiments which have thus far been completed have shown that the problem of finding a non-mercury carrot is indeed an empirical one. Since each step in the present process of preparing felt, with a mercury carrot, has been gradually perfected during the course of several centuries, it is not surprising, nor discouraging, to find that the early attempts to replace this carrot are not successful. Undoubtedly the adoption of a new carrot will involve the alteration of numerous small details in the routine procedure, in order to produce a felt of the quality that is now produced.

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# MINERS' NYSTAGMUS FROM THE POINT OF VIEW OF THE WORKMEN'S COMPENSATION ACT*

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THE publication of the "First Report of the Miners' Nystagmus Committee" (1) (referred to hereafter as the Report) brings into prominence the close connection between the incidence of certified cases of miners' nystagmus and the payment of compensation.

This aspect of the subject is dealt with in the present communication, and the data upon which it is based were collected by the writer for the use of the Committee. The expenses of the investigation were met by a grant from the Medical Research Council.

## Stages of the Disease

The primary symptom and physical sign of the disease is a rapid and rotatory oscillation of the eyeballs occurring among coal miners who have been employed below ground for a considerable period of time, amounting, on an average, to twenty-six years. The condition may be either latent or manifest.

During the latent stage, which may persist throughout working life, although the objective oscillation of the eyeballs is present, the miner is unaware of his condition, and experiences no disability. The latent stage, which may be short or long, passes into the manifest stage either suddenly—following upon an accident or some concurrent illness, such as influenza—or gradually. At this stage surrounding objects appear to dance and revolve before the sufferer, and vision fails, particularly at night and for skilled work; at the same time mental irritation often develops with post-cranial headache and broken sleep. When the disease reaches this stage, continued work below ground becomes impossible.

Cessation of work underground for from six to twelve months is generally followed by the disappearance of all objective signs, and usually results in permanent cure, especially if the miner is suitably employed. If he returns to underground work, however, relapse may take place. But during this convalescent stage, especially when compensation has been established, the subjective symptoms already referred to may be converted into a well-marked and persistent neurosis.

## Findings of the Committee

Before entering upon further discussion of the disease it will be well to refer to the main conclusions of the Committee, which are as follows:

1. The essential factor in the production of miners' nystagmus is deficient illumination. Other factors, such as position during work, accidents, alcoholism, infections, malnutrition, hereditary predisposition, and errors of refraction, are of secondary importance only, while depth of workings, thickness of seams, and the ordinary gaseous impurities in mine air have no direct influence on the disease.

2. The deficient illumination is due to the low illuminating power of the safety lamps generally used by coal miners, to the distance at which these lamps have to be placed from the objects at which the miner has to look, and to the great absorption of light by the

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coal and the coal-dust covered surfaces. In addition the effect of coal dust or dirt in obscuring the lamp glasses, the choking of the wire gauze chimneys, and the presence of moisture or low oxygen percentage in mine air, all reduce the light given by oil lamps; while failing voltage, poor bulbs, or lack of proper attention, have similar effects on illumination given by electric lamps.

3. Workers at the coal face are more affected than other underground workers, and this appears to be due to the unrelieved blackness of the coal and the greater need for accurate vision.

4. Distinct signs of nystagmus are present in a large proportion of coal miners, though only in a small proportion do the symptoms ever become so severe as to cause even temporary incapacity for work underground.

The Committee recommends that since incapacity due to nystagmus is rare among coal miners working with open lights, everything possible should be done to make the standard of illumination of the objects looked at by the miner equal to that of an open-light pit. This can be effected at the coal face and elsewhere either by greatly increasing (to about two or three candles) the illuminating power of safety lamps as ordinarily used, or by the use of an electric light capable of being fixed on a miner's head, belt, or other convenient position, so that the light is automatically brought nearer the working area and does not impair clear vision by shining directly into the eyes. At parts of the pit other than the coal face the visibility of objects can be greatly increased by whitewashing, as well as by the stone dusting now obligatory for the prevention of explosions. The Committee believes that by the application of these remedies miners' nystagmus of sufficient severity to cause disablement can, by degrees, be entirely prevented.

## Incidence of the Disease

*In Great Britain.*—On May 22, 1907, miners' nystagmus was added to the schedule of industrial diseases in the Workmen's Compensation Act of 1906. For the period before that date no accurate information in regard to the prevalence of the disease is available. The number of cases receiving compensation has steadily risen since that year, taking a big jump in 1913–1914, when the definition of the disease was altered by the order of the Secretary of State, July 30, 1913, from the original description "Nystagmus" to "The disease known as miners' nystagmus, whether occurring in miners or others, and whether the symptom of oscillation of the eyeballs be present or not." Information relative to the incidence of cases since 1908 is embodied in Table 1, which has been taken from the Report, and in part is shown graphically in Figure 1.

*In Other Countries.*—In Germany, from 1908-1912, 18.2 per cent. of the invalidity claims on the Bochum Miners' Union were for nystagmus. The number of cases per 1,000 in the period from 1905-1909 was 3.29; from 1910-1913, 3.25. In 1913 owing to a decision of the Superior Court, by which it was held that only serious cases of nystagmus were entitled to compensation, the number fell to 1.81. Stassen (2), in Belgium, and Dransart (3), in France, estimate the rate of total incapacity to be about two cases in every thousand workmen. It may be taken that the total incapacity rate for the four countries—United Kingdom, France, Belgium, and Germany—is 0.2 per cent. of the men employed underground. In America, where the disease is not certifiable, the incidence is very small and, with the exception of a valuable summary of European literature by Hoffman (4), practically nothing has been written on the subject.

The number of men who show nystagmus on examination is much higher than 0.2 per cent. Stassen (2), who has examined 11,000 miners, gives the percentage rate as 24.2; other authors (5) give similar figures.

## Economic Loss

The amount of compensation paid for all industrial diseases in the mining

dustry in Great Britain has risen from 13,382 in 1908 to £371,071 in 1920. This increase has been almost entirely due to nystagmus, and it may be assumed that in 1920 nearly £300,000 were paid in compensation for this disease alone. The loss falls on workmen, employers, and the state. The workmen, to whom health and working ability are

TABLE 1.—SHOWING PERCENTAGE INCIDENCE AND NUMBER OF CASES RECEIVING COMPENSATION FOR THE FIRST TIME DURING THE YEAR, TOTAL NUMBER OF CASES RECEIVING COMPENSATION DURING THE YEAR, COST OF ALL INDUSTRIAL DISEASES, NUMBER OF MEN EMPLOYED UNDERGROUND, NUMBER OF CASES DISABLED IN THE MINING INDUSTRY, AND OUTPUT IN TONS PER UNDERGROUND WORKER PER YEAR

| Year | Fresh Cases of Nystagmus | | Total No. of Cases of Nystagmus | Cost of All Industrial Diseases £ [1] | No. of Men Employed Underground | Accidents (1,000s) | Output in Tons per Man per Year |
|---|---|---|---|---|---|---|---|
| | Percentage Incidence | Number | | | | | |
| 1908 | 0.05 | 386 | 460 | 13,000 | 783,000 | 137 | 334 |
| 1909 | 0.08 | 631 | 1,011 | 26,000 | 805,000 | 154 | 328 |
| 1910 | 0.11 | 956 | 1,618 | 42,000 | 834,000 | 166 | 317 |
| 1911 | 0.16 | 1,375 | 2,519 | 68,000 | 849,000 | 167 | 320 |
| 1912 | 0.16 | 1,376 | 3,195 | 85,000 | 865,000 | 167 | 301 |
| 1913 | 0.26 | 2,402 | 4,551 | 113,000 | 895,000 | 195 | 321 |
| 1914 | 0.32 | 2,774 | 5,992 | 164,000 | 835,000 | 179 | 318 |
| 1915 | 0.24 | 1,780 | | | 743,000 | | 341 |
| 1916 | 0.20 | 1,626 | not | | 782,000 | not | 328 |
| 1917 | 0.18 | 1,461 | available | | 799,000 | available | 311 |
| 1918 | 0.24 | 1,917 | | | 783,000 | | 291 |
| 1919 | 0.29 | 2,718 | 6,449 | 225,000 | 933,000 | 134 | 246 |
| 1920 | 0.29 | 2,865 | 7,028 | 343,000 | 978,000 | 134 | 235 |

[1] Home Office returns do not separate cost of nystagmus from other industrial diseases. Nystagmus is responsible for over 90 per cent. of this cost.

everything, are reduced from an active life and a position of comparative affluence to dependence on weekly compensation. Home comforts are lost, the children are turned out into the world sooner than they otherwise would be, and the family tends to become restricted. The employer pays £300,000 a year in compensation, loses his best workmen, and finds his coal output reduced. The state loses the coal output of 6,000 men, which with the sum spent on compensation may be estimated at £1,000,000 a year (6). The indirect effect of the shortage of coal on other industries must also be taken into account.

In Great Britain under the terms of July, 1921, upon which the coal stoppage was settled, the workmen's wages are regulated by the financial results of the working of the industry. The pre-war wage rates are taken as the standard; to these are added the costs of production other than wages, together with an agreed percentage for profit to the owner. If the total of these charges is less than the proceeds realized from the sale of the coal, 83 per cent. of the surplus is added to the previous wage and expressed in the form of a percentage upon the basis rates. Workmen's compensation payments are part of the cost of production, and accordingly increased compensation means a reduction of any surplus available for wages. It is, then, in the interest of all parties—state, employer, and workmen—that the compensation costs should be kept low.

*Effect of Unemployment.*—After the coal dispute in 1921 several collieries experienced difficulty in finding work for all their employees. In one colliery, employing 650 men underground,

in which three cases had been certified in 1920, it was impossible to find work for 250 men when the pits restarted. Within six weeks eighteen of these 250 men were certified as disabled by nystagmus. Altogether twenty-three cases were certified between July and November 20, 1921, but there was not a single case from among the 400 men who returned to work when the pit started.

During the year thirty cases in all were certified from this pit. Assuming that each case costs the company £200, a liability of £6,000 was incurred in one year from nystagmus alone, a sum sufficient to pay a dividend at 6 per cent. on a capital of £100,000. In small companies a run of nystagmus cases such as this would cause serious financial embarrassment and might even lead to failure.

*Effect of Reduced Wages.*—Figure 2 shows the drop in the daily wage of the collier since March, 1921, and the monthly rate of incidence of miners' nystagmus in a district employing 20,000 men underground. The universal experience in the English coal fields is that there has been a great increase in the incidence of the disease following unemployment and reduced wages.

## Influence of Compensation

The workmen and employer differ very widely in their opinions of the incapacity caused by nystagmus. The employer points out that little was heard of the disease until compensation could be obtained, and that even at the present time the disease is rare in America where no compensation is allowed. The colliery manager says that the sequel to giving a man notice is the production of a certifying surgeon's certificate of disability for nystagmus; that many men can and do work with nystagmus; but that the younger generation gives up work at once.

From January 1, 1920, the maximum compensation was increased from 25 to 35 shillings a week. This was followed by a great increase in the number of compensation cases, and in North Staffordshire the figures for the first quarter of 1921 were 40 per cent. greater than those for the corresponding period of 1920. The great increase in the amount of compensation paid for all industrial diseases in late years (see Table 1) is entirely due to miners' nystagmus.

Compensation also enters into the question of surface employment. If a miner afflicted with nystagmus is employed on the surface, he is entitled to half the difference between his present and his former average wage (the half difference not to exceed £1). The underground wage is higher than the surface wage and the employer may be called upon to pay as much as £1 in half difference in addition to the ordinary surface wage. It is undoubtedly true that many men pursue a "ca'canny" policy and make no honest attempt to do a good day's work. They make so many stipulations as to the kind of work which they can perform, and are so irregular in their attendance that the employer is forced to the conclusion that they are not worthy of employment, and prefers to pay full compensation rather than employ them on the surface where they will corrupt the morale of his regular workmen by the slack manner in which they perform the work.

Mr. Gillhespy (7), general manager of the Yorkshire Coalowners' Mutual Indemnity Company, in his evidence before the Workmen's Compensation Committee in 1919, stated that an ex-

amination by Dr. Moxon of a typical Yorkshire pit, employing 2,000 men, showed that from 25 to 38 per cent. (according to the grade of employment) of all men over 21 years of age working underground showed oscillation of the eyes. Every one of these men could obtain a certifying surgeon's certificate and be legally disabled. In the great majority of cases the oscillation of the eyes produces no incapacity, and should not in itself entitle the man to compensation. Mr. Gillhespy says that the result of the scheduling of the disease has been to increase the incidence from thirty in 1907 to 515 in 1918. Thus:

Question 5677: There is one cause and one cause only — that is the chief thing — to account for this difference, and that is compensation.

Question 5715: It follows from that, that the difference in numbers must of necessity import the element of ungenuineness? To this extent, that they were legally genuinely disabled, but not in fact disabled. Also, unless the law makes the definite assumption that men with nystagmus can work, and must work, on the surface at the end of say six months, and unless the law definitely fixes the reduction to be enforced in the compensation, employers will be helpless, as a man with nystagmus can always allege that he is unable to work even on the surface, and to ask an employer to prove a man's fitness is simply asking an employer to attempt the impossible. Now the next paragraph is why I am here. Looking at the subject from the point of view of the men themselves, up to 1907, 30 men per annum were disabled. Now 515 men are disabled. The 485 additional men (515 less 30) themselves sacrifice one-half the wages they might be earning. The men themselves in the aggregate are thus unquestionably much worse off than if nystagmus had never been added to the Schedule of the Workmen's Compensation Act. If the deduction is also made that the disability in each case has grown as much as the number of claims has grown, the amount lost by the men each year, in wages, is huge. That is why I have come here, Sir. I want to show you this, that nystagmus was put into the Schedule of the Act at the request of the men and for the benefit of the men.

Mr. Gillhespy's facts are indisputable; it is probable that 25 per cent. of all men over 21 working underground could obtain a certifying surgeon's certificate and be legally disabled. In the light of our war experience, however, it is necessary to take a broader view than the one expressed by Mr. Gillhespy.

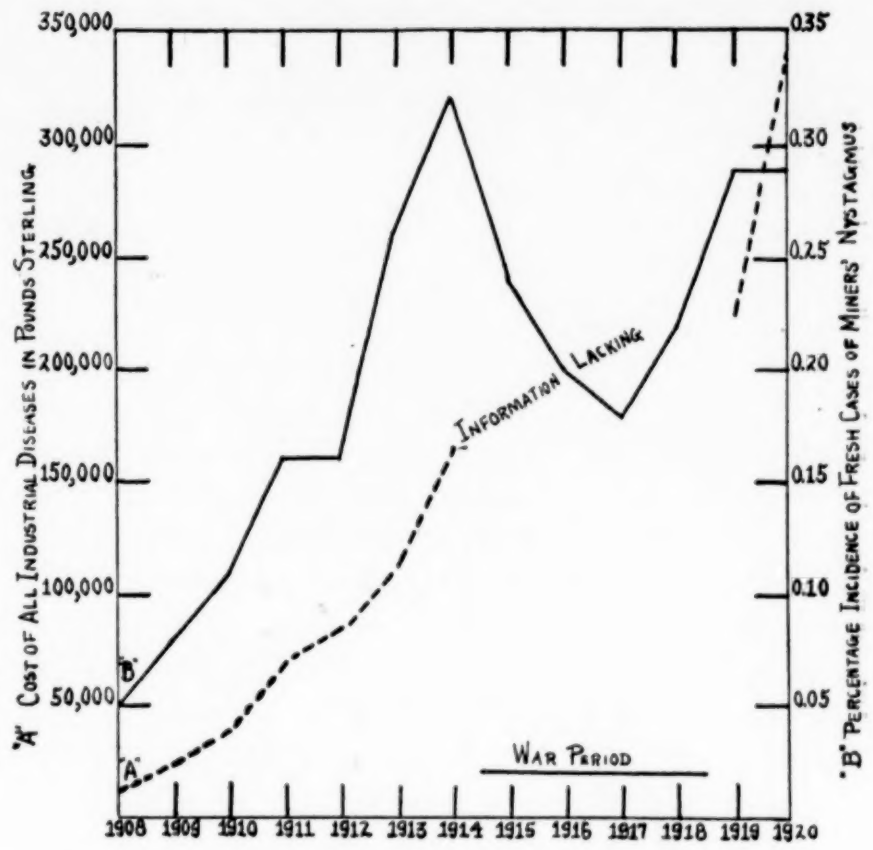


FIG. 1.—Showing incidence of fresh cases of miners' nystagmus (the figures given for the war years are only approximate), and cost from 1908 of all industrial diseases in the mining industry.

*Psychoneurotic Factors.*—War physiology has shown that many men placed in a position of danger or in uncongenial surroundings unwittingly react to their environment, and develop a neurosis of some form in order to escape. In the same manner the soldiers of industry who are unfit for or unsuited to their occupation develop a neurosis which brings them relief. If in addition to freedom from uncongenial work the release is associated with pecuniary advantages, the unconscious motive is doubly strong — one might even be tempted to say that it is quadrupled. It is quite common nowadays to hear colliers referring to the pit as the "hole"—a word of sinister meaning,

and a term which the writer does not remember hearing from a normal collier.

As an example of the development of psychoneurotic symptoms, may be instanced the prevailing belief among coal miners that permanent loss of sight results, if underground work is continued. This belief results partly from the failure of sight, which is common in the acute stages of the disease, and partly from the bad advice given by some medical men who threaten their patients with loss of sight if underground work is persisted in. In regard to this belief the Report states that:

> During its investigations the Committee has noticed the prevailing belief among coal miners that miners' nystagmus causes permanent damage to, or even total loss of sight, if underground work is continued after the onset of symptoms. This belief, which is entirely erroneous, has led to much unnecessary suffering and to the development of psychoneurotic symptoms in many cases. The disablement resulting leads to great loss to the miners, and increases the charges on the industry and general public.

In the Report Dr. Rivers sums up the relationship between incidence of the disease and compensation as follows:

> The bearing of the psycho-neurotic aspect of miners' nystagmus upon the problems connected with compensation is more definite. We are here presented with a situation closely comparable with that presented by pensions in relation to the psycho-neuroses of war. There is no question whatever that the perfectly legitimate and praiseworthy measure by which those disabled as the result of the war should receive monetary compensation has through the highly complex nature of psycho-neurosis led to the actual production, and still more largely to the prolongation, of disability to work. Similarly, the great increase in the prevalence of disabilities from miners' nystagmus since the introduction of compensation shows that this measure, as legitimate and praiseworthy as the compensation of sufferers from the war, has through the complexity of the state produced a great increase in the prevalence of psycho-neurotic affections. It is quite certain that compensation has not increased the prevalence of nystagmus in the strict sense. It is solely through its action upon the psychical and psycho-neurotic aspects of the disorder that the increased frequency of disability has come about.

The leading article on the Report published in the *Lancet* (1922 *1*, 855) says: ". . . since the introduction of compensation the prevalence of disabilities from miners' nystagmus has vastly increased; there is no question whatever, as Dr. Rivers insists—and in this his contention will be bourne out by all who have to do with the problem of the neurasthenic war pensioner—that monetary compensation has led to the actual production, and still more to the prolongation, of disability to work." The reviewer proceeds to say that if the condition is largely due to a psychoneurosis "It is the man as much as the defective illumination that has to be put right. Immense, indeed, is the problem for industrial psychology that is brought before us."

American readers will recall the psychological experiments carried out in the later years of the war with the idea of fitting the right man into the right place. Although it is far from the writer's intention to advise the coal owners to engage a body of psychiatrists, it might be possible, with a slight extension of the school medical service, to attempt a vocational selection of boys about to leave school.

## Intercurrent Illnesses

Many men quite honestly attribute the symptoms of the onset of disease to nystagmus. These men, who may have had a little inconvenience from a slight degree of nystagmus, persuade themselves that their present incapacity is due to

nystagmus. Other men knowingly take advantage of their legal right to compensation. The following case reports are cited as examples.

Case 1.—J. B., aged 64, while proceeding to work, collapsed and was brought home suffering from heart failure and acute bronchitis, from which he nearly died. His relations became anxious and sent in a claim to the company for "bronchitis brought on by work in the pit." This claim was ignored. The doctor then noticed that the man had oscillation of the eyes, and as a result a certificate of disablement by nystagmus was eventually obtained. The appeal by the company, on the ground that although the man showed nystagmus it was not the cause of his incapacity, was dismissed by the medical referee who, while not disputing the employer's contention, maintained that as the man showed nystagmus the appeal must be dismissed and the man entitled to full compensation.

Case 2.—W. T., aged 70, having a well-marked case of paralysis agitans, produced a certificate of disablement by nystagmus, when his real incapacity was due to disease.

Case 3.—R. E., aged 55, had recently been discharged from employment. While trespassing on a field he fell into a ditch and hurt his knee. The accident was in no way caused by nystagmic vision. He first tried unsuccessfully to claim damages against the farmer. He then obtained a certificate for "beat" knee, against which the employers successfully appealed. His next move was to obtain a certificate of disablement from nystagmus, and as oscillation of the eyes was present no appeal could be made.

These cases and data afford some ground for the belief almost universally held by employers that many men have taken unfair advantage of the provisions of the Workmen's Compensation Act, and have used the compensation which they can legally claim as a form of unemployment pay or old wage pension.

## Certification

The process of certification is briefly as follows. Under the present regulations of the Workmen's Compensation Act, 1906, a man suffering from nystagmus must produce a certificate of disablement from the certifying surgeon of his district before he is legally entitled to compensation. The employer has the right of appeal against this certificate, within seven days of its receipt, to the medical referee, whose decision is final. If the employer does not appeal, the certifying surgeon's certificate is final, and the man is legally totally incapacitated. If the man says that he is unfit for any work, the employer has no redress beyond taking the case into the County Court, a most unsatisfactory procedure.

The present definition of the disease in the schedule to the Act is a very broad one, and opens the way for the inclu-

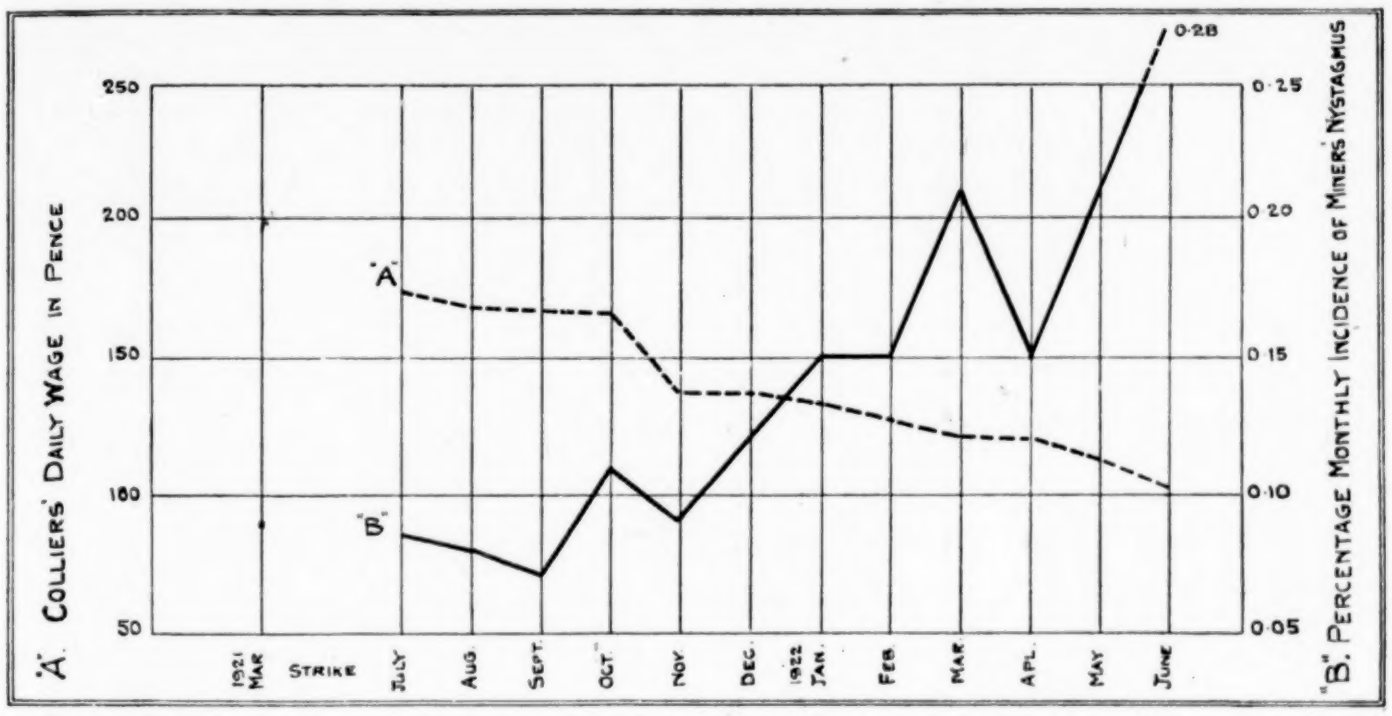


Fig. 2.—Showing rise in incidence of miners' nystagmus coincident with fall in wages.

sion of cases which are not those of miners' nystagmus. The certifying surgeon should not make the diagnosis of miners' nystagmus on the history given by the patient unless there is confirmation by physical examination. Rotatory and rapid oscillation of the eyes, true lid spasm associated with photophobia, head tremor (when combined with head resistance and backward inclination), and objective giddiness, may separately be considered sufficient to confirm diagnosis when accompanied by a typical history.

Irregular movements of the eyes, rolling about of the eyes, and blinking may all be purposive. Above all it is important to realize that a miner may develop a psychoneurosis quite apart from his underground life and, although he will probably refer his symptoms to his oculomotor apparatus, it by no means follows that the pit work is the cause of his incapacity. In all these cases the certifying surgeon must satisfy himself that objective signs are present, and he should not grant a certificate on a man's history alone. If he does, he will confirm the man in his neurosis and do him an unintentional injury.

## Measures for the Prevention and Limitation of Incapacity

*Preliminary Eyesight Test.*—In addition to the various recommendations for the improvement of underground illumination made in the Report, some other suggestions for the prevention of the disease and the limitation of incapacity have been made. The writer (6) in 1920, when suggesting that a preliminary eye test should be carried out before engagement of the workman, proposed that a simple method would be for the official employing the man to make a rough estimate of his eyesight with the ordinary test letters, and to refuse him employment without a medical examination, if he has less than 6/12 vision.

This method has been carried out in the North Staffordshire coal field since 1913, but without any real measure of success. It was strongly advocated by Anderson in 1920 (8). Anderson maintains that only men with refractive errors develop nystagmus of sufficient severity to cause incapacity, and that every effort should be made to prevent them from obtaining employment underground. Here again the services of the school medical officer might be utilized, and a certificate of freedom from refractive error, obtained upon leaving school, should be in possession of youths seeking underground employment. The etiological importance of error of refraction is under debate, but the writer's opinion is that, even if it is not a factor in the actual production of the disease, it is a factor in the incapacity which results. For this reason steps taken to prevent the entry into the pits of lads and men with refractive error will eventually lessen the incidence of certified cases of nystagmus.

*Necessity for Recertification.*—The writer, in 1920, also suggested that the period of total incapacity should be limited, and that the men should be required to produce fresh certificates yearly, against which the employer should have the right of appeal under the machinery already existing. The Miners' Nystagmus Committee has adopted this principle of periodic right of appeal, and recommends that both workman and employer be granted power to appeal to the medical referee, at intervals of not less than six months from the date of the original certificate of disablement or the

date of last appeal, in order to assess the incapacity present. In this appeal the medical referee should certify that the man is either:

1. Totally incapacitated.
2. Partially incapacitated.
   a. Fit for surface work.
   b. Fit for suitable work below ground.
3. Not incapacitated.

*Limitation of Incapacity.*—The second principle advocated—that of limiting the period of total incapacity—is not without precedent, as glass workers' cataract entitles the workman to compensation for only six months. Generally speaking, all symptoms and signs of miners' nystagmus are lost after the man has left the pit for two years, often long before this time. Men only slightly afflicted can work on the surface without any delay. Cases in which the psychoneurotic element is marked run a very different course. The man may allege total incapacity years after he has left the pit, and long after all signs of the disease have disappeared. It might be thought that if the compensation of these men were cut down or stopped a hardship would be entailed; but these men, through the instability of their nervous systems, were from the first unfit for pit work and their breakdown was not entirely due to pit work. It is a well-known fact that 25 per cent. of all underground workers over 20 years of age show the physical signs of the disease but are free from symptoms. Some men develop the disease within a few months, while others work underground for years without any inconvenience. There must, then, be a personal factor which largely determines both the onset of the disease and the incapacity resulting from it.

The suggestion may now be made that compensation should automatically drop to two-thirds in the second year, and to one-third in the third year, at the end of which period it should cease, subject to an appeal to the medical referee, the onus of proof to rest on the workman.

TABLE 2.—RETURNS FROM MUTUAL INDEMNITY SOCIETIES FOR THE YEAR 1920

| District | Percentage Incidence of Nystagmus | Cases Settled | Cost per Case in Year £ | Percentage of Cases Working | |
|---|---|---|---|---|---|
| | | | | Underground | Surface |
| A . . . . | 0.68 | 0 | 32 | 10.39 | 68.83 |
| B . . . . | 0.54 | 0 | 34 | 29.11 | 42.62 |
| C . . . . | 1.40 | 2 | 47 | not available | |
| D . . . . | 0.58 | 12 | 32 | 49.5 | 21.0 |
| E . . . . | 1.88 | 169 | 112 | 3.0 | 33.5 |
| F . . . . | 1.14 | 5 | 39 | 28 per cent. receive no compensation | |
| G . . . . | 0.80 | 10 | 30 | 74 per cent. at work | |
| United Kingdom | 0.72 | | | | |

*Lump Sum Settlements.*—The alternative to the failure or rejection of the last two policies is that of lump sum settlement. The difficulty which the nystagmic workman has in finding surface employment at his own colliery has a very prejudicial effect on his recovery. Employment above ground, after a short preliminary rest in severe cases, is the only specific cure for nystagmus.

One of the great advantages of lump sum settlement is that it leaves the workman free to find in the open market work which, although not so remunerative as his old employment, helps in his recovery. Both workman and employer have to cut their losses and the former, if paid off, does not allow himself to drift into

the ranks of the "chronics" and unemployables. Table 2, taken from the Report, throws some doubt, however, on the wisdom of general lump sum settlements.

The high incidence of the disease, the low rate of return to work, and the high cost of the individual cases in district E appear to be directly related to the policy of settlement. In this district the men and their leaders are keenly alive to the advantages of lump sum payments. It is quite common, however, for the men to return to work underground after a lump sum settlement has been made. The geological conditions, methods of work, and life history of the cases show little difference from similar conditions in neighboring coal fields.

It is policy, for example, to settle as soon as possible a case of broken leg, if the injury is such that return to pit work is unlikely. One broken leg case does not lead to another; one nystagmus case may lead to two or three. The temptation of a man, who knows that he has nystagmus, to ask for a lump sum when he hears that his neighbor has just been paid off for the same complaint, is very great,—too great, in fact, for many workmen in times of stress. It follows, then, that although in the individual case the policy of settlement is sound, in the aggregate its wisdom is very doubtful. It might be policy for the employer to settle only long-standing cases, of two or more years' duration, for a sum equal, for instance, to three years' compensation. The workman should remember that these long-standing cases are due to a neurosis for which the underground work is not primarily responsible.

## Conclusion

It would be ungenerous to conclude this paper without paying tribute to the majority of the underground workmen. No one who has had any experience with the disease can fail to be struck with the dogged courage shown by the afflicted. Many men hold on to breaking strain, and force their wills to overcome the many handicaps of the disease.

One may picture the suffering workman waiting behind at the pit bottom to allow the lamps of his fellow workmen to get out of sight, slowly developing his adaptation to darkness, and groping his way to the coal face where he is for a time more at ease. The constant stooping and bending soon set up oscillation of his eyes and the place swims before him. He cannot find any tool which he may happen to drop; he stumbles over loose lumps of coal; he knocks his head against the roof but still struggles on more by the sense of touch than by the sense of sight. At the end of the shift he waits behind in order to avoid the rush of the younger men, and finally reaching the surface has the same difficulty in his adaptation to light that he had on descent. In the old days the miner afflicted with nystagmus was often met at the pit top by his wife or child, and taken home. The giddiness which he develops keeps him at home through fear of being mistaken for a drunken man; the photophobia sends him to bed when the lamps are lighted; while headaches and disturbing dreams spoil his night's rest. These are the conditions under which many men show an endurance, not for one glorious moment, but for months, and their simple statement "I went as long as I could" chronicles a struggle of which any man might be proud.

## Summary

1. The incidence of certified cases of miners' nystagmus has greatly increased since the introduction of compensation,

while unemployment and low wages have a similar effect.

2. The incapacity caused by the disease is largely due to the development of psychoneurotic symptoms.

3. The economic loss caused by the disease in Great Britain is at least £1,000,000 a year.

4. The following measures for the prevention and limitation of incapacity are recommended:

a. A preliminary eye test before engagement.

b. Provision of surface work.

c. Right of periodic appeal to a medical referee.

d. The automatic and gradual limitation of the amount of compensation paid.

e. A restricted policy of lump sum settlements.

f. The expansion of the school medical services for vocational selection of boys suitable for work underground.

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# OBSERVATIONS UPON THE EFFECTS OF EXPOSURE TO ARSENIC TRICHLORIDE UPON HEALTH*

THE LATE SHERIDAN DELÉPINE, M.B., C.M., M.Sc.

## PREFATORY NOTE

A WORKMAN employed during the war period in England upon the commercial production of arsenic trichloride died following the accidental spilling of some of this fluid over his right leg. This fatality led to an inquiry into the true cause of death, and to an examination of the conditions under which arsenic trichloride is manufactured and of the dangers to which the workmen are exposed. Laboratory research was undertaken to investigate (*a*) the local caustic action of arsenic trichloride, (*b*) the absorption of the poison through the skin, (*c*) the results of inhaling its vapor, and (*d*) the way in which risk to the workmen might be avoided. The paper which follows embodies the results of these different inquiries and investigations.

## INVESTIGATION INTO A FATALITY FOLLOWING SPILLING OF ARSENIC TRICHLORIDE UPON THE LEG

The deceased, a man aged 47, was employed in the manufacture of arsenic trichloride at a chemical works. The appearance of the leg is indicated in Figure 1. Examination of the organs and products of the body gave the results embodied in Table 1.

In order to stop putrefaction the organs, with the exception of the stomach, were immersed in a small amount of formaldehyde solution (carefully tested and free from arsenic). No formaldehyde was added to the blood. After a few days a fairly large amount of arsenic was found to have been taken up by the formaldehyde solution, and as time went on the amount of arsenic which could be recovered from the organs was found to have materially diminished. The same phenomenon was observed in samples of urine containing arsenic to which formal had been added.

The large amount of arsenic found in all the organs examined indicated that some soluble compound of arsenic had been freely distributed through the body, in all probability by the blood and lymph. The considerable amount of arsenic present in the liver can be explained by the well-known tendency which the poison has to be stored up in this organ. The large amount of arsenic found in the lung cannot be explained in the same way, and strongly suggests that shortly before death the patient had inhaled air laden with arsenic in some form. How much arsenic was absorbed through the skin of the leg cannot be inferred from the results of the postmortem examination.

The microscopic examination of the organs showed that the heart, liver, kidney, pancreas, and the gastric and duodenal glands were in a state of acute granulo-fatty degeneration; in addition to this, the liver and kidney showed slight chronic interstitial changes. The parenchymatous lesions were undoubtedly the result of acute arsenicism; the

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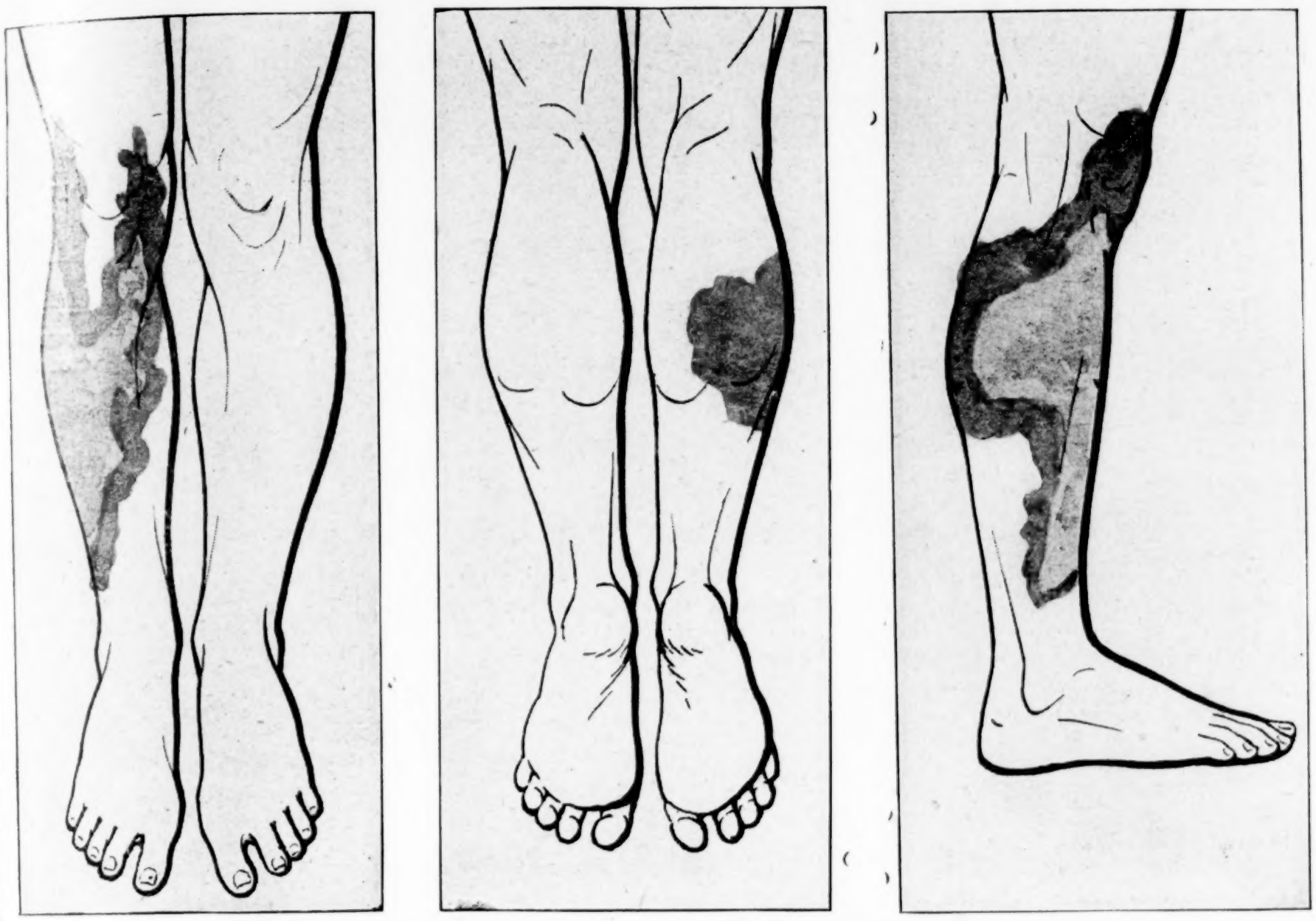

FIG. 1.—Appearance of leg after arsenic trichloride had been spilled upon it.

chronic interstitial lesions may or may not have been caused by chronic poisoning of the same kind. The state of the lungs also suggested the sudden action of some very irritating gas.

Owing to the fact that the patient suffered from suppression of urine almost from the first hours of his illness, death may be attributed to failure of the kidney, but the state of the lungs was sufficient to cause death, and the lesions of the liver, pancreas, and heart would also have been fatal more or less rapidly. The actual cause of the death was, therefore, *acute arsenicism*.

These findings indicated that men engaged in the same work as that on which the deceased was employed were probably exposed to very material danger, even in the absence of such an accident as that which brought about the fatal issue. The changes and the amounts of arsenic found in the various organs indicated that in all probability the cutaneous lesion was not the only channel through which arsenic had penetrated; and that the man had breathed air heavily laden with poison.

Under the supervision of Dr. A. E. McKenzie specimens of hair and also samples of urine were obtained from two men who had been engaged on the same work for six months. Both samples contained a material amount of arsenic. In addition to this, the presence of a large amount of purin bodies and of indican suggested the existence of degenerative changes in the tissues. The amount of arsenic found in the hair was considerable. The bulk of it was in the substance of the hair, for, after boiling it for one hour with 13 per cent. hydrochloric acid and extracting a first quantity of arsenic, a still larger quanti-

ty was obtained by boiling the hair again for two hours in 13 per cent. hydrochloric acid. The results of the examination of these samples are shown in Tables 2 and 3.

TABLE 1.—APPROXIMATE ESTIMATE OF THE AMOUNT OF ARSENIC PRESENT IN ORGANS AND PRODUCTS AVAILABLE FOR EXAMINATION

| Organ or Material[1] | Average Weight of Organs | Actual Weight of Organs of Deceased | Value of Sublimate Obtained by Reinsch-Delépine Method per Gram of Original Material | Calculated Amount of Arsenic Trioxide in Material Examined | |
|---|---|---|---|---|---|
| | | | | Moderate Estimate[1] | Maximum Estimate[2] |
| | *gm.* | *gm.* | *mg.* | *gm.* | *gm.* |
| Liver, after immersion in formaldehyde for 10 days (S.D.) | 1,579 | 1,475 | 0.09 | 0.13275 | – – |
| (f) Liver, after immersion in formaldehyde for 1 day (H.H.) | 1,579 | 1,475 | (0.2) | – – | 0.295 |
| Left lung (S.D.) | 618 | 830 | 0.02 | 0.0166 | – – |
| (f) Left lung (H.H.) | 618 | 830 | (0.10) | – – | 0.083 |
| Right lung | 682 | – – | – – | 0.01364 | – – |
| Left kidney | 277 – – | 319 159 | – – | (0.00318) | – – |
| (f) Right kidney | – – | 160 | 0.02 | 0.00320 | – – |
| Pancreas | 102 | 102 | 0.025 | 0.00255 | – – |
| (f) Stomach | 200 | – – | 0.0025 | (0.0005) | – – |
| (f) Heart | 400 | 380 | 0.005 | 0.0019 | – – |
| (f) Blood of heart | approximate amount of blood about 4,000 | ? | 0.0033 | 0.0132 | – – |
| (f) Blood of heart, lung, and kidney | | | | | |
| Omental fat | – – | – – | 0.015 | – – | – – |
| Bile | – – | – – | present | – – | – – |
| Urine | – – | – – | present | – – | – – |
| First formal extract (liver, 500; lung, 400; pancreas, 60; kidney, 40; reduced to 350 c.c.) | – – | 350 | 0.06 | 0.021 | – – |
| Second formal extract of the same (not reduced) | – – | 650 | 0.0016 | 0.00104 | |
| | | | | 0.20956[3] | |

[1] All the organs had been kept for several days in 4 per cent. formaldehyde solution except those marked (f), which had been kept only a few hours in the solution.

[2] In organs nearly fresh.

[3] According to the maximum estimates 0.22865 should be added, making a total of 0.43821.

## Methods of Analysis

The method devised nearly three hundred years ago by the Dutch chemist, Glauber, is still in use for the preparation of arsenious chloride, or trichloride of arsenic ($AsCl_3$). It consists in distilling a mixture of arsenic trioxide with sulphuric acid and sodium chloride. The commercial product used was prepared according to this method. It is an oily, very mobile fluid, having a slight brownish color (pure arsenic trichloride is colorless), and, when exposed to ordinary air, it emits fumes and evaporates fairly rapidly. It is very poisonous and has well-known caustic properties (caustic oil of arsenic). When it is mixed with less than the quantity of water necessary to decompose it completely, an oxychloride of arsenic ($AsO, Cl, H_2O$) is produced. When a larger amount of water is employed, the final

products are hydrochloric acid and arsenic trioxide, the greater part of the latter being precipitated.

Ammonia gas is absorbed by arsenic trichloride with the production of a white solid, for which various formulae have been given by some of the earlier workers (H. Rose, Pasteur, and Michaelis). For the present purpose, $2\ AsCl_3, 7\ NH_3$ (Rose) will be sufficient simply to indicate in a broad way the nature of some of the changes which may be expected to take place in mixtures of air and arsenic trichloride vapors. The phenomena observed suggest the existence of many intermediary products which must be of considerable theoretical and practical interest to chemists.

In all the experiments performed for the purpose of ascertaining the effects of arsenic trichloride upon the health of workers and other persons, crude arsenic trichloride from a factory was used. In the experiments devised for the study of the mode of diffusion in the air, in addition to the crude product, some pure arsenic trichloride was used for purposes of comparison. The close resemblance between the results obtained with the pure and with the commercial products showed that the effects observed were chiefly, if not entirely, due to arsenic trichloride.

TABLE 2.—APPROXIMATE AMOUNT OF ARSENIC IN HAIR AND URINE OF TWO WORKMEN AT SAME PLANT AT WHICH DECEASED WAS EMPLOYED

| Name | Material | Amount Available for Analysis[1] | Value of Sublimates Obtained by the Reinsch-Delépine Method from 1 Gm. of Material | Calculated Amount of Arsenic Trioxide Passed in Urine in 24 Hours |
|---|---|---|---|---|
| | | *gm.* | *mg.* | *gm.* |
| H. H.[2] | Hair | 0.297 | 2.64 | .... |
| P. W. G.[2] | Hair | 0.235 | 3.78 | .... |
| | | *c.c.* | | |
| H. H. | Urine | 750 | 0.00196 | 0.001470 |
| P. W. G. | Urine | 360 | 0.00223 | 0.000802 |

[1] Only a small amount of hair was available, because the men kept their hair very short. The urine is the whole amount for twenty-four hours.

[2] H. H., aged 45; P. W. G., aged 35. Both men had been regularly employed at the plant for six months.

TABLE 3.—GENERAL CHARACTERISTICS OF THE URINE OF TWO WORKMEN EXAMINED

| | *H. H.* | *P. W. G.* |
|---|---|---|
| Color | Dark reddish yellow; on standing became dark sherry color | Reddish yellow, not so dark as that of H. H.; on standing became darker |
| Sediment | On standing, amorphous pale urates deposited first, then uric acid and large octahedral crystals of oxalate of lime. Yeasts were numerous | Same as in case of H. H., but on standing neither uric acid nor oxalate of lime separated. Yeasts were abundant |
| Specific gravity | 1030 | 1027 |
| Acidity | Considerable, increased on standing for several days | Same as in case of H. H. |
| Albumin | No appreciable amount | No appreciable amount |
| Glucose | " " " | " " " |
| Bile pigment | " " " | " " " |
| Indican | Very abundant | Present, but less abundant than in case of H. H. |

*Hydrochloric-Copper Method.*—In the early parts of this investigation the only method used was one described briefly in the *British Medical Journal,* Jan. 12, 1901[1], and more fully in evidence given before the Royal Commission on

[1] Delépine, S.: The Detection of Arsenic in Beer and Brewing Material. Brit. Med. Jour., 1901, *1*, 81.

Arsenical Poisoning. This method is suitable for the direct analysis of animal and vegetable products containing arsenious compounds, and it makes possible the detection of 0.01 mg. of arsenic trioxide in 100 gm. of fluid (corresponding to a dilution of 1 in 10,000,000). In this method trichloride of arsenic is first produced, then arsenide of copper, which is then converted to arsenic trioxide and collected in the form of a crystalline sublimate in suitable sublimation tubes. For short, this method is referred to as the hydrochloric-copper method.

When the amount of arsenic in 100 gm. of the material corresponds to more than 0.01 and less than 0.1 mg. of arsenic trioxide, it is possible to estimate with approximate accuracy the amount of arsenic present in the material, by comparing the sublimates obtained with standard sublimates. In order to obtain more accurate estimates, it is necessary to bring the amount of arsenic in the amount of material tested to between 0.02 and 0.05 mg. This can easily be done by concentration or dilution of the original material.

Fluids, such as urine or solutions obtained by washing air or various articles in suitable solvents, can be dealt with directly. To 100 c.c. of these fluids, 20 c.c. of arsenic-free hydrochloric acid and two equal pieces of arsenic-free copper foil having an aggregate surface of 144 sq. mm. are added. This mixture is kept boiling uninterruptedly for two hours. The two pieces of copper are then thoroughly washed and dried, and one of the pieces is carefully heated in a sublimation tube of standard size.

Solids, such as hair, liver, kidney and other organs, previous to being treated as described in the foregoing, are disintegrated by being boiled for about two hours with as much arsenic-free hydrochloric acid and water as is necessary to bring the proportion of strong hydrochloric acid to one-third of the total mixture. To prevent loss of arsenic trichloride, all these operations are conducted in flasks provided with reflux condensers.

We were convinced that, after exposure to arsenic trichloride fumes for a comparatively short time, hair and other products became laden with a large amount of arsenic, and that ordinary volumetric methods, such as the iodine method, would, therefore, be sufficiently delicate for practical purposes. This view was confirmed by the results obtained by Mr. Heap, who was entrusted with the volumetric estimations of the arsenious compounds collected in the various fluids or on the surface of the test plates used in connection with experiments upon the distribution of arsenic trichloride in the air. This method of estimation was conducted by Mr. Heap as follows:

*Iodine Volumetric Method.*—When the arsenious compound is in solution in water the titration is made by rendering the solution quite alkaline with sodium bicarbonate, adding an excess of centinormal iodine solution, and titrating back the excess with standardized sodium thiosulphate. In cases where potassium hydrate has been used either as absorbent or as solvent for the arsenious compound, the potash is neutralized by the addition of an excess of hydrochloric acid; then the excess of acid is neutralized by careful addition of sodium bicarbonate, and afterwards an excess of sodium bicarbonate is added. This solution is titrated as stated above. From the amount of iodine required for oxidation, the quantity of arsenic present as arsenious acid is calculated.

It is possible by this method to estimate quantities of arsenious compounds

exceeding 0.025 mg. (0.000025 gm.). Results indicating quantities below 50 mmg. cannot be expected to have a high degree of accuracy.

Estimates of the amount of arsenic in some samples of hair were made by both the iodine method and the hydrochloric-copper method for purposes of comparison, and the results were found to be in general agreement. (The figures given in the sections relating to hair and urine have all been obtained by the hydrochloric-copper method; those relating to arsenic collected from the air, in fluid solvents, or on test plates have been generally obtained by the iodine method).

*Unit Used for Recording Purposes.*—For the purpose of making it possible to compare easily the proportional amount of arsenic in various animal or other products, it is convenient to take the millimilligram as a unit (0.000001 gm.) and to calculate the amount of arsenic (as arsenic trioxide) present in standard quantities of 100 gm. of solids or 100 c.c. of liquids. With regard to gases, 1,000,000 c.c. might be adopted as a standard quantity approximating roughly the solid and liquid standards (1,112,000 c.c. of hydrogen weigh 100 gm. at 0°C. and 760 mm. pressure. A cube with a 100 cm. side contains 1,000,000 c. c.).

The millimilligram unit is below the limit capable of direct estimation. The smallest amount which can be determined by direct observation when the hydrochloric-copper method is used is 1 cmg.; the adoption of the millimilligram unit is, however, convenient to avoid fractions in calculated results. The iodine method is less delicate and is open to various objections, but as an estimate can be made by a single analysis, it saves a considerable amount of time.

### Amount of Arsenic in Hair and Urine of Persons and Animals Exposed to Arsenic Trichloride Fumes, and of Other Persons and Animals

In summing up the results of this part of the investigation it will be convenient to divide them among the following groups:

A. Men engaged in the manufacture of arsenic trichloride.

B. Chemists frequently sampling and testing arsenic trichloride.

C. Patients treated with organic arsenical preparations taken internally.

D. Persons working in a laboratory where experiments involving the occasional handling of arsenic trichloride are conducted.

E. Animals not exposed to arsenic trichloride fumes.

F. Laboratory worker, experimenting with arsenic trichloride under favorable conditions, before and after short exposures to the fumes.

G. Animals exposed experimentally to arsenic trichloride fumes.

The main results are summed up in Table 4; other cases and fuller details will be found in later sections.

### Effects of Experimental Exposures to Arsenic Trichloride Fumes

The animals used in these experiments were rabbits, guinea-pigs, rats, and mice. The experiments were attended with some difficulty on account of the mobility of the fluid and of the diffusibility of the vapors; this was a source of trouble not only on account of the care which had to be exercised in order to limit the action of the poison, but also on account of the unpleasant effects which the experimenter experienced at times.

The experiments may be divided into

TABLE 4.—AMOUNT OF ARSENIC FOUND IN HAIR AND URINE OF PERSONS AND ANIMALS EXPOSED TO ARSENIC TRICHLORIDE FUMES AND OF SOME OTHER PERSONS AND ANIMALS

| Group | Subject | Date | Arsenic per 100 Gm. of Hair *Mmg.* | Arsenic per 100 C.C. of Urine *Mmg.* | Remarks |
|---|---|---|---|---|---|
| *Amount of Arsenic in Hair and Urine of Persons in Groups A, B, C, and D* | | | | | |
| A. Persons engaged in manufacture of arsenic trichloride | H. | Sept. | 264,000 | 220 | After a short period of rest following material exposure. |
| | | Oct. | 500,000 | 80 | After one month's work under improved conditions. |
| | | Dec. | 6,000 | under 10 | After two months' suspension of work. |
| | G. | Sept. | 378,000 | 250 | After short suspension of work after material exposure. |
| | | Oct. | 600,000 | 80 | After one month's work under improved conditions. |
| | | Dec. | 25,000 | under 10 | After two months' suspension of work. |
| | A. | Nov. | 22,500 | " " | After suspension of work for several weeks. |
| | B. | " | 75,000 | " " | After suspension of work for several weeks. |
| B. Chemists engaged in sampling and testing arsenic trichloride | K. | Oct. | 80,000 | 55?<br>10 | Preventive precautions not long in force. |
| | | Nov. | 60,000 | under 10 | One month later. |
| | J. | Oct. | 75,000 | 40<br>40 | " " " |
| | | Nov. | 45,000 | under 10 | " " " |
| | H. | Jan. | 280,000 | — | Chemist engaged in work at B. R. plant (arsenic trichloride). |
| C. Patients taking arsenic internally, not exposed to arsenic trichloride | 9523 | Dec. | 8,000 | 36,000 | Ends of long hair only examined (female). |
| | 9524 | " | 7,000 | 8,000 | Ends of long hair only examined (female). |
| D. Persons working in a laboratory where occasional analyses of arsenical products are conducted. Seldom exposed to arsenic trichloride and then to a very slight extent. All dwellers in a large industrial town | H. H. | Oct. | 4,000 | — | Chemical work chiefly. |
| | S. D. | " | 3,000 | under 5 | Experimental biological work chiefly. |
| | E. I. | " | 1,000 | " " | Clerical work chiefly; end of long hair, covered by other hair (F). |
| | F. S. | " | 3,000 | — | General laboratory worker. |
| | F. D. | " | 3,000 | — | Laboratory work, including the use of arsenical solutions. |
| | R. C. | " | 2,500 | — | General work and glass blowing. |
| | R. F. | " | 1,000 | — | General laboratory work. |

two main groups: (1) inunction experiments—namely, those in which arsenic trichloride was applied to the skin (the respiratory organs being protected); and (2) inhalation experiments.

In all these experiments crude arsenic trichloride was used. Its properties corresponded in all important particulars with those of pure arsenic trichloride prepared at the laboratory.

### *Direct Application of Arsenic Trichloride to the Skin*

The object of these experiments was to ascertain not only the nature of the

TABLE 4.—*Continued*

| Group | Subject | Date | Arsenic per 100 Gm. of Hair *Mmg.* | Arsenic per 100 C.C. of Urine *Mmg.* | Remarks |
|---|---|---|---|---|---|
| | | *Amount of Arsenic in Hair of Animals Kept in Town* | | | |
| E. Animals in animal house. Not exposed to arsenic trichloride | rabbit | Oct. 16 | 1,500 | — | Coke fire beginning. Dorsal hair chiefly. |
| | 6 guinea-pigs | Dec. 21 | 4,000 | — | Coke fire for two months. Dorsal hair. |
| | | *Amount of Arsenic Found in Hair of One Person and Several Animals Exposed Experimentally to Arsenic Trichloride Fumes* | | | |
| F. Laboratory worker before and after exposure to arsenic trichloride | S. D. | Oct. 16 | 3,000 | — | Before beginning experiments with arsenic trichloride. |
| | " " | Dec. 16 | 6,000 | — | After carrying out occasional experiments with arsenic trichloride in the course of six weeks. |
| | " " | Dec. 21 | 19,000 | — | Three hours after visiting an arsenic trichloride plant. |
| | " " | Jan. 28 | 40,000 | — | Eight days after making experiments with the 215,000 c.c. chamber. |
| G. Animals exposed experimentally to arsenic trichloride fumes | guinea-pig | Dec. 8 | dorsal, 35,000 | — | Forty-five minutes' exposure to fumes scarcely visible near inlet of chamber. |
| | | | ventral, 27,500 | — | |
| | | " " | dorsal, 40,000 | — | Companion to guinea-pig in above experiment. |
| | | Dec. 16 | ventral, 12,000 | — | |
| | " " | Dec. 11 | — | — | One hundred and fifty minutes' exposure to invisible fumes of arsenic trichloride. |
| | " " | Dec. 21 | dorsal, 21,000 | — | Dorsal hair of two guinea-pigs clipped ten days after exposure. |
| | " " | Dec. 11 | dorsal, 95,000 | — | Forty minutes' exposure to dense visible fumes of arsenic trichloride. |
| | " " | " " | dorsal, 70,000 | — | Companion to guinea-pig in above experiment. |
| | " " | Jan. 18 | dorsal, 100,000 | — | Eighty-eight hours after exposure to dense arsenic trichloride fumes. |
| | " " | " " | dorsal, 160,000 | — | Eighteen hours after exposure to air loaded with arsenic trichloride. |

local lesions, but also to what extent absorption took place through the skin, and thus exposed the animal to general poisoning.

Immediately after arsenic trichloride is applied to the skin, a bulky light cloud arises from the treated part and continues to be visible in a gradually diminishing degree for about twenty to thirty minutes. In order to prevent the vapors from reaching the respiratory passages, it was necessary to drive the fumes away from the mouth and nose by causing a current of air to pass over the animal from head to tail. For this purpose a strong current of air was produced by an

electric fan, and the fumes were driven out of the room through an open window immediately behind the animal.

Except in one experiment, in which a small fraction of the fluid crept up accidentally along the skin, only the distal half of the tail of each rat was treated. This arrangement permitted the tail to be thoroughly washed by dipping and agitating it in a large amount of water at definite intervals in order to remove that portion of the caustic which had not already penetrated into the tissues. Arsenic trichloride was applied to the skin by means of a 0.25 c.c. or of a 0.10 c.c. glass pipette. The fluid appeared to dry rapidly, the hair and skin becoming rapidly covered by a white efflorescence. After being kept under observation for some time, the animals were transferred to cages in which their excreta could be collected. After the death of each animal a postmortem examination was made, and various tissues or organs were taken for microscopic and chemical examination.

Owing to the smallness of the organs in the rat, it was difficult to estimate with much accuracy to what extent arsenic passed into the subcutaneous tissue and how it was distributed in the various organs. It was, therefore, necessary to use a rabbit. The animal was placed with its tail toward an open window, and during the experiment air was driven from head to tail so as to cause the animal to breathe only fresh air. Then 0.12 c.c. of arsenic trichloride was applied to the back of the inner border of each ear, so as to cover only the distal two-thirds of the organ over a width of 1 to 2 cm. After an interval of one minute one of the ears was washed with an abundant stream of water, after which it was dried with filter paper. The other ear was washed five minutes after treatment.

The application of arsenic trichloride was at once followed by evidence of sharp pain which subsided almost immediately, the part treated becoming rapidly insensitive, but the skin in the immediate neighborhood was painful when touched. The application of water was apparently painful at first, but the pain disappeared rapidly. The roots of both ears remained painful to the touch until the animal died.

The same efflorescence which had been noticed in the experiment on the rat was obvious. This was reduced by washing but reappeared when the ear again became dry. When the ears were apparently dry, the animal was removed to its cage, where it remained quiet and showed no sign of pain nor any desire to escape.

The following is a summary of the results of four experiments in which arsenic trichloride was applied to the skin of animals.

EXPERIMENT 1.—This consisted in the application of 0.25 gm. of arsenic trichloride to the greater part of the tail of a white rat. The tail dried rapidly and was afterwards covered with a white efflorescence. Death occurred an hour and a quarter after the application of the arsenic trichloride.

The amount of arsenic (as arsenic trioxide) found by postmortem examination was as follows:

| | Mmg. per 100 Gm. |
|---|---|
| Liver | 3,320[1] |
| Hair of back and sides (It is possible that some fluid had spread up the skin of the back.) | 20,000 |
| Middle part of tail | 25,000 |

[1]Owing to an accident, this estimate is not reliable; the actual amount of arsenic in the liver was probably quite small. It seemed desirable, however, to record all the results obtained.

EXPERIMENT 2.—In this experiment 0.25 gm. of arsenic trichloride was applied to the distal half of the tail of a white rat. The fluid, however, spread along the skin toward the root of the organ. After a minute and a half, the distal half of the tail was washed in water; a minute and a half later the tail was washed again up to about 2 cm. from its root,

and was dried with filter paper. The rat was killed three days and eight hours after the application of the arsenic trichloride.

The amount of arsenic (as arsenic trioxide) found by postmortem examination was as follows:

| | Mmg. per 100 Gm. |
|---|---|
| Brain | 3,900 |
| Liver | 740 |
| Muscles and bones of neck, thorax, and anterior lumbar region (limbs, head, posterior lumbar and sacral region not included) | 468 |

EXPERIMENT 3.—In this experiment 0.1 gm. of arsenic trichloride was applied to the distal half of the tail of a white rat. Fumes were visible for thirty minutes. The hair rapidly became coated with a white efflorescence. Death occurred three days and five hours after exposure.

The amount of arsenic (as arsenic trioxide) found upon examination was as follows:

| | Mmg. per 100 Gm. |
|---|---|
| Liver | 600 |
| Bones and muscles of sacrum and lumbar region | 220 |
| Urine collected between fourth and fifty-ninth hours | 520 |
| Feces passed during second and third days, and the contents of the colon postmortem | 6,000[1] |

[1]There may have been some arsenic introduced by external fumes and supporting board.

EXPERIMENT 4.—Arsenic trichloride was applied to the back of the inner border of each ear of a rabbit over the length of 6 cm. from the top, and over a width of about 1½ cm. (0.12 gm. was applied to each ear). One minute after the application, the left ear was thoroughly washed with 300 c.c. of water squirted over it, after which it was dried with filter paper. Five minutes after the application the right ear was washed in the same way.

The amount of arsenic (as arsenic trioxide) found upon examination was as follows:

| | Mmg. per 100 Gm. |
|---|---|
| Brain | 1,050 |
| Nose, mucous membrane, hard palate, nasal bone, nasal part of upper maxilla (external nostrils removed) | 5,500 |
| Lungs | 16,000[1] |
| Liver | 4,000 |
| Kidneys | 1,080 |
| Hair, dorsal | 10,000 |

[1]This figure is doubtful.

| | Mmg. per 100 Gm. |
|---|---|
| Subcutaneous tissue, root of left ear edematous connective tissue only | 48,720 |
| Side of head, temporo-pterygoid region, including some edematous muscular tissue, but no skin or bone | 9,120 |

### *Inhalation Experiments*

In these experiments two types of experimental chambers were used, one of which was of large size and permitted the study of the effects of vapors of arsenic trichloride when they were in the presence of an excess of air. To study the effects of short exposures to air uniformly charged with arsenic trichloride vapors, much smaller chambers were used which made it possible to replace the normal air rapidly by a current of air containing a known quantity of arsenic trichloride.

*Inhalation of Fumes of Arsenic Trichloride in Presence of an Excess of Air.*—The experimental chamber used in these experiments had a capacity of about 215,000 c.c. (allowing for the space occupied by animals, cages, etc.). This chamber could accommodate several small animals at the same time (allowing 60 liters of air per pound per hour for the respiratory needs of small animals there was more than enough air in the chamber for four guinea-pigs of moderate size, even when the air was not renewed for one to two hours).

This chamber was also used for studying the distribution of arsenic trichloride fumes by various methods, including the test plate method, which is described in later sections of this report. (The same apparatus was used in experiments on the effects of sewer air upon health. See Report to the Sewer Ventilation Committee of the Manchester Corporation, 1909.) The chamber measured 102 cm. in length, 46 cm.

in height, and 46 cm. in width. It was closed above by means of a thick glass plate, the joint between the glass plate and the flange surrounding the opening of the chamber being made air-tight by means of a bed of vaseline clay. In later experiments adhesive plaster was found more convenient. At each end of the tank there was a tubular opening through which tubes of various sizes up to 1 inch in diameter could be fixed. These tubes served as inlet and outlet tubes, respectively, and by means of suitable elbows the levels and position of the inlet and outlet tubes could be adjusted.

In the first two experiments the animal cages were supported by a perforated floor at a height of 6 cm. above the opening admitting the gas. In the subsequent experiments the perforated floor was removed, and the cages were laid on the floor, two cages near the inlet and two cages near the outlet. These cages were made of wire net and allowed free circulation of gases during the experiments.

To introduce arsenic trichloride fumes into this chamber, air was sometimes caused to bubble through a very thin layer of arsenic trichloride placed in a suitable, comparatively large gas washing bottle. At other times the air was made to pass over the surface of the arsenic trichloride contained in a small light conical flask. The distance between the ends of the inlet and outlet tubes in the small flask was about 2 cm. The surface of arsenic trichloride exposed at the bottom of the flask did not exceed 7 cm. square. This arrangement was particularly useful because the flask was light, and could be closed and weighed accurately immediately before and after each experiment. It was thus possible to estimate to 1 cg. the amount of arsenic trichloride which had been vaporized and had mixed with the measured amount of air that had passed over it.

In several experiments made respectively with air dried over sulphuric acid or with air almost saturated with water, it was found that at a temperature of 15° to 17°C., when the flask contained 2.34 gm. of arsenic trichloride, about 0.09 to 0.13 gm. of the arsenic trichloride was abstracted in five minutes by the passage of 3,300 c.c. of air over the surface of the fluid. (When the air was caused to flow over the fluid by reduction of pressure in the large chamber, great irregularities were observed, probably owing to the difficulty of avoiding leakages. The most concordant results were obtained by blowing air under slight pressure over the surface of the liquid arsenic trichloride.)

When moist air is passed continuously over arsenic trichloride, a thin layer of watery-looking fluid containing hydrochloric acid forms over the surface of the brownish fluid which becomes distinctly turbid. The rate of vaporization is then diminished. The same change occurs when arsenic trichloride remains exposed to damp air for some time. When the object of the experiments was to estimate the effects of air containing definite proportions of arsenic trichloride, it was necessary to use fresh fluid for each experiment, and to reduce the duration of the exposure to a few minutes. The details of the experiments performed in the large (215,000 c.c.) chamber follow.

Experiment 5. — A stream of damp air charged with arsenic trichloride was admitted to the large chamber by an inlet near the bottom of the chamber, which was covered with a thin layer of water. A guinea-pig was placed 6 cm. above the level of the inlet and 30 cm. from it. Fifty-four thousand centimeters of air passed over 1 c.c. of arsenic trichloride in fifty-five minutes. Thin

curly clouds of fumes rose to the upper part of the chamber in the neighborhood of the inlet. The air of this chamber was not generally cloudy. Death occurred four hours and twenty-five minutes after exposure.

The amount of arsenic (as arsenic trioxide) found in the hair of the guinea-pig was as follows:

| | Mmg. per 100 Gm. |
|---|---|
| Hair, dorsal..... | 35,000 |
| Hair, ventral..... | 27,500 |

The total amount of arsenic recovered at the end of the experiment was:[1]

| | Mmg. |
|---|---|
| Contents of wash bottle at outlet | about 640 |
| Calculated average contents of 215 liter chamber at end of experiment | about 2,750 |

(Most of the arsenic trichloride must have decomposed in the chamber and yielded deposits in the third of the chamber near the inlet.)

[1]These estimates are of doubtful value.

EXPERIMENT 6. — A guinea-pig was exposed at the same time as the guinea-pig in Experiment 5 but not quite so near the inlet and not so clearly on the path taken by the fumes (for details see Experiment 5). Death occurred ten days after exposure.

The amount of arsenic (as arsenic trioxide) found in the hair of the guinea-pig was as follows:

| | Mmg. per 100 Gm. |
|---|---|
| Hair, dorsal, twenty-four hours after exposure.... | 40,000 |
| Hair, dorsal, eight days after exposure..... | 12,000 |

The total amount of arsenic recovered at the end of the experiment was:[1]

| | Mmg. |
|---|---|
| Contents of wash bottle at outlet..... | 640[2] |
| Calculated contents of 215 liters of air at end of experiment (see Experiment 5)..... | 2,750[2] |

[1]See remarks under Experiment 5.
[2]Probably underestimated, only one absorption tube being used.

EXPERIMENT 7. — A stream of air charged with arsenic trichloride was admitted to the 215,000 c.c. chamber as in Experiments 5 and 6, but in this case the bottom of the chamber was dry. A guinea-pig was placed 6 cm. above and 30 cm. from the inlet. Thirty thousand cubic centimeters of air were allowed to pass over 1 c.c. of arsenic trichloride in 120 minutes (somewhat intermittently). Small clouds issued at intervals from the inlet. The animal was left eighty minutes longer in the chamber. The clouds rose at once to the top of the chamber, rolling slowly toward the outlet but dispersing before they reached the middle of the distance between the inlet and the outlet. At no time was the chamber entirely filled with fumes.

The guinea-pig was killed forty-six days after exposure. By analysis the following amounts of arsenic (as arsenic trioxide) were found:

| | Mmg. per 100 Gm. |
|---|---|
| Liver ..... | doubtful trace |
| Hair (A) equally mixed dorsal hair of guinea-pigs of Experiments 7 and 8, clipped ten days after exposure..... | 21,000 |
| Hair (B) of same guinea-pigs clipped forty-five days after exposure.... | 4,000 |

The total amount of arsenic recovered was as follows:[1]

| | Mmg. |
|---|---|
| White deposit formed on plate in chamber on a surface 78.5 cm. square ..... | over 80,000 |
| Calculated deposit on total area of floor of chamber and animals (area of floor 4,692 sq. cm.).. | 597,000 |
| Contents of two absorption tubes and water at outlet of chamber | 891 |
| Calculated contents of air in chamber at end of experiment | 6,237 |

[1]See remarks under Experiment 5.

EXPERIMENT 8.—The guinea-pig used in this experiment was exposed along with the guinea-pig in Experiment 7. The details of the experiments are the same. The animal died ninety-seven days after exposure. No analyses were made.

EXPERIMENT 9. — A stream of air was charged with arsenic trichloride by being blown through a thin layer of the fluid before being admitted to the 215,000 c.c. chamber through an inlet at the upper part of the chamber. A guinea-pig was placed 30 cm. below the inlet and at a distance of about 70 cm. from it. Thirty liters of air passed over the arsenic trichloride in forty minutes. The guinea-pig was left in the chamber eighty

minutes after the end of the passage of air laden with the fumes. The inlet half of the chamber rapidly filled with dense fumes, which completely hid the bottom of the chamber. The guinea-pig died in less than eighteen hours after exposure.

By analysis the following amounts of arsenic (as arsenic trioxide) were found:

| | Mmg. per 100 Gm. |
|---|---|
| Stomach and intestine.... | 227 |
| Hair, dorsal..... | 95,000 |
| Muscles of bones and trunk, after removal of head and all viscera..... | 45 |

The total amount of arsenic recovered was:[1]

| | Mmg. |
|---|---|
| Contents of two absorption tubes of water and of potassium hydroxide at outlet of chamber..... | 3,514 |
| Calculated arsenic content of air in chamber at end of experiment..... | 24,598 |

[1]See note under Experiment 5.

EXPERIMENT 10.—This was a duplicate of Experiment 9. The only difference was in the weight of the animals. The guinea-pig died in less than eighteen hours.

The following amounts of arsenic (as arsenic trioxide) were found:

| | Mmg. per 100 Gm. |
|---|---|
| Liver and one kidney..... | 1,494 |
| Hair, dorsal..... | 70,000 |

For the calculated arsenic content of the air in the chamber, see Experiment 9.

EXPERIMENT 11. — (See also Experiments 12, 13, and 14.) A stream of air was passed over arsenic trichloride and was then freed from suspended particles and excessive moisture by passage through 15 per cent. sulphuric acid before admission to the 215,000 c.c. chamber, by the upper inlet. Ten liters of air laden with arsenic trichloride passed through the chamber in thirty minutes. (During the first ten minutes about 3 liters of air were lost.) About 0.252 gm. of the arsenic trichloride evaporated. A rat was placed on the floor of the cage 37 cm. below the level of the *inlet* and 20 cm. on one side of it. In this part of the chamber fumes were not visible. They were most marked in the middle third of the chamber. In the outlet third they were visible but not so thick as in the middle. The rat lived for ten days and was then used for Experiment 15.

From the second to the fifth day of the experiment 38 c.c. of urine were collected, and of this amount 19 c.c. were used for chemical analysis. Only a doubtful trace of arsenic was found.

EXPERIMENT 12. — The arrangement was the same as that in Experiment 11, except that the rat was placed at a distance of 20 cm. on one side of the *outlet* and 37 cm. below its level. (The distribution of fumes was the same as in Experiment 11.) The rat died within four days after exposure.

The following amounts of arsenic (as arsenic trioxide) were found by analysis:

| | Mmg. per 100 Gm. |
|---|---|
| Liver ..... | less than 82 |
| Urine (19 c.c. passed in three days before death) | 105 |
| Hair, dorsal, clipped post-mortem four days after exposure ..... | 72,000 |

EXPERIMENT 13. — The arrangement was the same as that in Experiment 11. The guinea-pig was placed at the same distance from the *inlet* as the animal in Experiment 11, but on the opposite side (see remarks under Experiment 11 about the distribution of fumes). This experiment was partly spoiled because the guinea-pig escaped and went to the outlet part of the chamber during the exposure. Death resulted in less than eighty-eight hours after exposure.

The following amounts of arsenic (as arsenic trioxide) were found:

| | Mmg. per 100 Gm. |
|---|---|
| Nasal soft tissue and bones, including palate (olfactory lobes excluded).... | 3,600 |
| Brain and cerebellum..... | 4,800 |
| Lungs ..... | 1,440 |
| Liver, average of two estimates made..... | 1,405 |
| Kidneys and adrenals..... | 6,840 |
| Hair, dorsal..... | 100,000 |

EXPERIMENT 14. — The arrangement was the same as that in Experiment 11. The animal was placed at the same distance from the *outlet* as in Experiment 12, but on the opposite side of it. (The distribution of fumes was the same as in Experiment 11.) Death occurred in less than eighteen hours after exposure.

By analysis the following amounts of arsenic (as arsenic trioxide) were found:

| | Mmg. per 100 Gm. |
|---|---|
| Nose and soft part with upper maxillary and palate bones (skin and superficial muscles and brain excluded) | 6,720 |
| Lungs | 805 |
| Liver | 2,000 |
| Hair, dorsal | 160,000 |

EXPERIMENT 15. — (See also Experiment 16.) Arsenic trichloride fumes were allowed to diffuse in the still air of the 215,000 c.c. chamber. Arsenic trichloride (0.25 c.c.) in a shallow capsule was placed at a height of 23 cm. above the floor of the chamber. A rat was placed in a wire cage about 20 cm. below the capsule, and almost immediately under it. The chamber was closed hermetically (after the rat of Experiment 16 had also been placed in it). A test plate placed 20 cm. above the arsenic trichloride was covered with a thick white deposit at the end of the experiment. A test plate 20 cm. below the capsule was covered with a thinner deposit (see also Experiment 16). The duration of exposure was six hours and forty-five minutes. Death resulted in less than forty-five hours after exposure.

The amount of arsenic (as arsenic trioxide) found in the liver and hair of the rat was as follows:

| | Mmg. per 100 Gm. |
|---|---|
| Liver | 832 |
| Hair, dorsal | 20,000 |

The following amounts of arsenic were recovered from the deposits on the test plates:

| | Mmg. |
|---|---|
| Plate 20 cm. above capsule | 6,400 |
| Plate 20 cm. below capsule | 3,200 |
| Plate 55 cm. above capsule | 2,400 |
| Plate 55 cm. below capsule | 2,400 |

EXPERIMENT 16. — The arrangement was the same as that in Experiment 15, but the rat was placed at a distance of 50 cm. laterally from the arsenic trichloride capsule. Test plates were placed at the level of the animal and at a height of about 40 cm. above it in positions corresponding to those of the plates placed immediately above and below the capsule. The amount of deposit on these distant plates was much smaller than on the other plates (see Experiment 15).

The rat was quite well after ten days, and was not killed.

*Inhalation of Air Uniformly Charged with Definite Amount of Arsenic Trichloride and not Allowed to Mix afterwards with Ordinary Air.*—A small glass chamber (of 140 c.c. capacity), in which a mouse could easily be accommodated, was used for this series of experiments, the object of which was to determine the pathogenic effects of air containing a definite amount of arsenic trichloride. Two smaller chambers (of 55 c.c. capacity) were also used simultaneously, for the purpose of comparing the effects upon two mice of the same mixture of air and arsenic trichloride, one-half of which had been caused to pass through a wet sponge (Fig. 2).

The 140 c.c. chamber was originally designed for experiments upon the exhaust gases from internal combustion engines. The mouth of the chamber, through which the animal was introduced, was closed by a large glass stopper. An outlet tube, provided with a glass stopcock, was connected with the chamber close to its mouth, and at the opposite end of the chamber there was an inlet tube also provided with a stopcock. When ordinary air was made to pass freely through this chamber by connecting its outlet with an aspirator or its inlet with a blower, a mouse could live in it comfortably for many hours and without showing any sign of discomfort.

Owing to the small size of the chamber and to the position of the head of the mouse, which was quite close to the inlet opening, it was easy to submit the animal to exactly timed exposures to gaseous mixtures of definite composition, and to watch closely the effects.

In all the experiments two 10-liter aspirators were used either to force air into, or to abstract air from, the experimental chamber. The lower openings of these bottles were connected by a long

india-rubber tube, and the upper parts of the bottles were connected with another tube of the same length as the first. This second tube had in its length a T-tube, each branch of which was provided with a glass stopcock. The upper opening of each bottle was also provided with a second tube with a stopcock. This formed a closed system in which the same amount of water could be used over and over again either to aspirate or to blow air through the experimental chamber and to collect in one bottle exactly the amount of air driven out of the other bottle. The object of this was to prevent an escape of poisonous fumes into the room. The cloudy fumes collected over water in one of the bottles gradually disappeared, and the gas could then be expelled without serious inconvenience.

The smaller twin chambers, used for comparing the effects of the same mixture of gas both filtered through a wet sponge and unfiltered, were used in the same way. In order to regulate the flow of gas, however, so as to insure that the same amount passed through the two chambers, a bubbling flask was connected with the outlet of each experimental chamber and the amount of gas admitted to each chamber regulated by taps until the amount issuing from one of the chambers was equal to that escaping from the other.

Previous to admission to the experimental chamber, the air was charged with arsenic trichloride by being made to pass over the surface of arsenic trichloride in the small flask previously described. The weight of this flask and its contents was taken immediately before and after each exposure, so that the amount of arsenic trichloride taken up by a measured quantity of air could be accurately ascertained. The air was sometimes dried by being caused to bubble through strong sulphuric acid, and was sometimes saturated with moisture by being made to bubble through water. This was done either before or after the air had been charged with arsenic trichloride. The details of the experiments made in these small chambers (of 140 c.c. and 55 c.c. capacity) follow.

EXPERIMENT 17.—Dry air was passed over arsenic trichloride and afterwards through sulphuric acid. The mixture as admitted to the experimental chamber was quite dry. Three thousand and three hundred cubic centimeters of air containing 0.11 gm. of arsenic trichloride passed through the chamber in five minutes. This dry mixture remained clear until it reached the inlet of the chamber, and then it became cloudy in the neighborhood of the head of the mouse. Forty-four minutes after exposure the mouse died.

EXPERIMENT 18.—Moist air was passed over arsenic trichloride and afterwards through a thin layer of water. Three thousand and three hundred cubic centimeters of moist air containing 0.13 gm. of arsenic trichloride passed through the chamber in five minutes (after being washed through a small amount of water). This damp mixture was quite cloudy after passing through the water, and the chamber was immediately filled with this cloudy mixture. The mouse used was quite well after twenty-one days.

EXPERIMENT 19.—In this experiment 3,300 c.c. of moist air, which had been passed over arsenic trichloride and which contained 0.09 gm. of arsenic trichloride, was admitted direct to the chamber. The air was uniformly cloudy after its passage through the arsenic trichloride, and the chamber was immediately filled with this cloudy mixture. The mouse used in this experiment died fifty-two minutes after exposure.

EXPERIMENT 20.—Two mice were exposed simultaneously for five minutes to the same quantity (3,400 c.c.) of air charged with 0.128 gm. of arsenic trichloride. In one case air from a flask of arsenic trichloride was passed through an intermediate chamber containing only a baffle to prevent suspended particles from being carried over to the 55 c.c. mouse chamber. The mouse died in fifteen minutes.

EXPERIMENT 21.—In the other the air from the flask of arsenic trichloride was passed

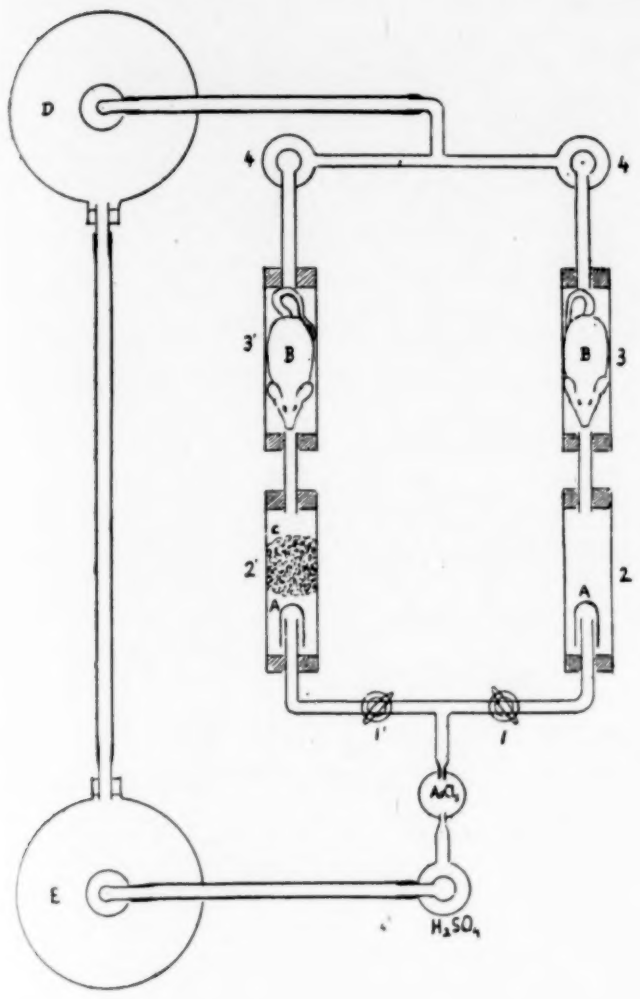


FIG. 2.—**Twin glass chambers for comparative** experiments on mice. (Scale 1 to 9.)

$H_2SO_4$=bubbling flask (containing strong sulphuric acid when dry air is desired, water when air saturated with moisture is desired, or nothing). $AsCl_3$=small flask containing arsenic trichloride. 1 and 1′=stopcocks on inlet tubes. 2 and 2′=intermediary chambers (2′ contains sponge C). 3 and 3′=mouse chambers. 4 and 4′=bubbling flasks used to estimate the rate of air current which is regulated by stopcocks 1 and 1′. A=part of intermediary chambers 2 and 2′ near baffle on inlet tube. B3=mouse exposed to untreated fumes; B3′=mouse exposed to air filtered through moist sponge C. C=moist sponge. D=aspirating flask. E=blowing flask.

through an intermediate chamber containing a baffle and, in addition, a wet sponge through which the gaseous mixture had to pass before being admitted to the 55 c.c. mouse chamber. With the exception of the sponge, this half of the apparatus was identical with that used for Experiment 20. The mouse was quite well at the end of twelve days.

### *Microscopical Lesions Observed after Inhalation of Arsenic Trichloride*

With the object of ascertaining the effects produced by arsenic trichloride fumes upon the large air passages, sections through the anterior parts of the nasal passages, the supraglottic and infraglottic parts of the larynx, and the lower part of the trachea were made in several of the cases. The histological changes in the lungs, liver, and kidney were also studied in nearly every case. The necessity of keeping material for chemical examination, and the smallness of the parts did not permit of an histological examination in every case.

Owing to an unfortunate mistake made in the preparation of the hardening medium, the reactions and appearances of most of the tissues were sufficiently altered to cast doubt upon the exact meaning of several of the finer cellular changes observed. For this reason the cellular changes are not dwelt upon in this summary.

*Air Passages, Anterior Parts of Middle Meatus and Inferior Meatus of Nose.*—A successful section made through the air passages of the rat used in Experiment 12 showed very little alteration in the mucous membrane, but the passages were obstructed by mucus containing many desquamated epithelial cells and a few red blood corpuscles. This animal had lived four days.

*Larynx.*—In cases in which death had supervened rapidly, no marked edema or desquamation of the epithelium was observed, nor was the mucous membrane covered by coagulable exudation in either the supraglottic, infraglottic, or glottic region. In animals that had lived more than twelve hours there was evidence of catarrhal laryngitis and tracheitis, but the lesions were not extensive.

The surface of the mucous membrane was free from exudation capable of causing obstruction. In one animal which had lived ten days, the mucous membrane of the trachea was covered at places with a fairly thick smooth layer of mucus containing many small round cells and nuclei apparently derived from

epithelial cells broken up in consequence of mucous degeneration. This exudation was most abundant over the openings of the tracheal mucous glands, and was firmly attached to the ciliated surface of the epithelial cells. The lungs of this animal were congested but free from hemorrhage, collapse, or pneumonic changes.

*Lungs.* — Considerable dilatation of the branches of the pulmonary artery and of the alveolar capillaries was a feature common to all cases. In animals which had died a few hours after exposure, there were patches of hemorrhagic infiltration in various parts of the lungs, and dilatation of the alveoli in intervening parts. Most of the small and terminal bronchi were contracted, but the bronchial epithelium appeared generally to be intact. In one guinea-pig which had lived eighty-eight hours after exposure (Experiment 13), clear evidence of catarrhal bronchitis was found. In a rat (Experiment 12) which had lived nearly four days, the lungs were distinctly edematous, many of the alveoli being filled with a clear exudate free from cells or fibrin.

For reasons already stated no confidence is placed upon the minute cellular changes which may be present in the liver or kidney. It appeared, however, that in animals dying early the liver cells showed a marked tendency to excessive vacuolation, while in the animals that had survived a few days the cells appeared to be smaller than normal. No trace of fatty degeneration of the liver was discovered in any of the cases. Considerable congestion of the liver and kidneys was a common feature. The rod-like structure of the basal part of the epithelium lining the convoluted renal tubules was generally more distinct than normal. There was no evidence of fatty degeneration of the kidneys.

### *General Summary of Experimental Results*

Death is frequently brought about either by the inhalation of air charged with arsenic trichloride fumes or by the direct application of undiluted arsenic trichloride to the skin. In both cases there is clear evidence that arsenic is absorbed by the tissues and that it becomes widely distributed in a very short time.

When arsenic trichloride is applied to the skin it produces necrosis very rapidly. Free washing with water of the part affected within one minute retards the action of the escharotic, and a certain amount of inflammatory reaction is observable in the parts adjacent to the affected region. Even after such washing, however, the whole of the part to which arsenic trichloride has been applied undergoes complete necrosis. Washing five minutes after application has no appreciable effect. A considerable amount of arsenic is rapidly absorbed by the tissues and after a few hours arsenic can be recovered from most of the tissues or organs of the body. There is noticeable a tendency to accumulation in such organs as the brain, liver, and kidneys.

The application of arsenic trichloride to the skin is obviously acutely painful, but the part affected becomes rapidly insensitive. It is doubtful, therefore, whether pain is a determining factor in the lethal action of arsenic trichloride applied to the skin. The fatal effect appears to be due to acute arsenicism.

When air charged with arsenic trichloride is breathed by mice for five minutes, death follows in a few minutes when the air, whether dry or moist, contains 1 part of arsenic trichloride to 40,000 parts of air. When a stream of air charged with arsenic trichloride is

admitted to a chamber containing an excess of ordinary air, animals kept in the chamber are affected variously. Some die after a few hours; others survive for several days and appear to recover entirely. In one experiment, of two guinea-pigs which were at a very short distance (a few inches) from each other one died in less than five hours, and the other lived ten days (Experiments 5 and 6). In another experiment conducted under the same conditions, except that the flow of charged air was less rapid and the exposure twice as long, both guinea-pigs made a complete recovery (Experiments 7 and 8).

These differences were caused by the unequal distribution of the mixture, which was due not only to the formation of an air stream between the inlet and outlet of the chamber, but to the reactions which took place between the arsenic trichloride, water, and the oxygen of the air. As will be shown in a later section of this paper, various motions are caused by these changes. After a few observations it was found that on both sides of the inlet of the chamber there was an area to which the arsenic trichloride fumes found slow access. The fumes were most abundant in the upper part of the chamber at a distance of 30 to 50 cm. from the inlet and were fairly, though less, abundant in the outlet half of the chamber including parts at the sides of the outlet corresponding to parts at the sides of the inlet where fumes were scanty. This observation was confirmed by an experiment in which a rat exposed at one side of the *inlet* (Experiment 11) was not much inconvenienced and was well ten days after exposure, while another rat (Experiment 12) exposed at the same time at one side of the *outlet* was almost immediately severely affected, and died in less than four days.

All the animals that died from the effects of the inhalation of arsenic trichloride showed marked symptoms of respiratory affection. In the animals in which death supervened rapidly the symptoms pointed distinctly to laryngeal obstruction, and death was clearly due to asphyxia. Postmortem examination did not reveal any organic cause of obstruction, such as plugs of mucus, false membrane, or edema glottidis.

The absence of organic obstruction, the extreme rapidity with which death followed after inhalation, and the suddenness of the onset of asphyxial symptoms point to the conclusion that laryngeal obstruction was due to spasm of the laryngeal muscles. The tendency to this spasmodic closure of the glottis continued after the animals had partly recovered, and a fatal ending was produced in a mouse (Experiment 19) as a consequence of its being slightly disturbed: it was breathing with some difficulty but was in no immediate danger; on being slightly disturbed, however, it made violent efforts to breathe, passed into convulsions, and died within two minutes. A guinea-pig (Experiment 12) which appeared to be recovering was liable to violent attacks of dyspnea, followed by convulsions, whenever it attempted to eat solid food or to drink.

Bubbling through a thin layer of water or filtration through a wet sponge deprives the air of the irritating properties giving rise to these laryngeal symptoms. The filtered air still contains arsenic though in smaller proportion than the unfiltered air. It contains much less chlorine, however, so that the irritation of the mucous membrane is probably in great part due to hydrochloric acid or some other chlorine compound. (The water squeezed out of the wet sponge is strongly acid.)

The hair of all the animals exposed to

arsenic trichloride fumes became rapidly laden with a considerable amount of arsenic. This was observed in animals that recovered as well as in those that succumbed to the effects of exposure. The poison was not only deposited on the surface but penetrated into the substance of the hair. This was clearly demonstrated by examination of the solution used for washing the hair, and of the products of disintegration of the hair when it was boiled in 30 per cent. hydrochloric acid. This impregnation of the hair does not appear to have any quantitative relation to the symptoms of poisoning, and the reason for examining the hair of persons and animals exposed to arsenic trichloride fumes was to ascertain the extent of the exposure. During life an examination of the urine and feces is necessary to determine whether such an exposure has led to absorption.

*(To be continued)*

# REPORT OF THE ASSOCIATION OF CERTIFYING FACTORY SURGEONS, INC. (GREAT BRITAIN), FOR THE YEAR 1921

THE last Report emphasized the wisdom of every certifying surgeon who holds an appointment which he regards of some value, making a point of becoming a Fellow or Member. Owing to the excellent financial position of the Association it has not, up to the present, been found necessary to advance the subscriptions, and with anything like a fair response to the appeal, this contingency will not arise. When non-members receive the same benefits of united action as members, it is surely not going too far to suggest to the former the reasonableness of giving their support and sharing the small expense.

## Departmental Committee on Blindness

The Hon. Secretary was invited by the British Medical Association to give evidence on behalf of that body on the industrial aspect of defective vision, and did so on 22nd March. The evidence itself cannot be dealt with until after publication of the report, but it may interest members to know the headlines. The first portion had concern with the large number of young persons with uncorrected errors of refraction who seek employment in factories, and with the particular discrimination exercised by certifying surgeons when required to give certificates in such occupations as the machining of wearing apparel, textile spinning, weaving, doubling, winding and reeling, working in iron, steel and other metal, sawing timber, wood working, machine boxmaking, flint glass and pottery processes, all of which require a considerable amount of acuity of vision on the part of the operator.

## Alteration in Annual Report

By instruction of the Council a letter was addressed to the Chief Inspector of Factories on 7th March, drawing attention to the circumstance that no particulars respecting conditional employment had been asked for as part of the two previous Annual Reports. (Sec. 64 (5) F. & W. Act, 1901.)

The views of the Association were explained as follows:

It appears to the Association that Sec. 122 (6), F. & W. Act, 1901, requires a record of all young persons ascertained by medical examination to be physically defective, and of the action taken by the certifying surgeon with respect to such. The word "results" is used, and as this signifies more than rejections a return confined to these cannot cover the obligations.

Apart, however, from the strict legal requirement, it is considered of public interest that a full record of the "results" of these medical examinations should be available. The system of conditional certificates, in spite of its imperfections, is regarded as having greatly extended the usefulness of the certifying surgeon, and as being of proved benefit to large numbers of young people on commencing their industrial career.

I have to point out that the action taken by the certifying surgeon, as a result of the defects found, depends as a rule more on the nature of the industry and its capacity for providing suitable alternative employment than on the nature of the bodily disease or infirmity *per se*, so that any particular defective may be totally rejected at one factory and certified conditionally at another. The bulk of defectives may therefore be said to be of one class, dealt with in two different ways according to varying circumstances. The incomplete return at present asked for cannot possibly give any idea of the discrimination exercised in dealing with these young people, and is therefore unfair to the surgeon as well as misleading to the public.

Whilst the former publication in your Annual Reports of a complete summary of conditions attached to certificates of fitness has undoubtedly served a useful educative purpose, in view of the labour entailed in compiling the table, the Association does not press for its renewal. On the other hand, it is respectfully suggested that a full classification of all those found affected with disease or bodily infirmity should be published under two divisions, *viz.*, (1) rejections, and (2) certified conditionally. This would simply mean the adding of a third column to Table II.

The Chief Inspector expressed through Dr. Legge his agreement with the views of your Council, and further suggested that it would be well, when altering the form of report, to revise the list of medical reasons for rejection, and that in any such revision the Association might usefully co-operate with Dr. Legge. The old classification has always been regarded as unsatisfactory by the Association, the consequence being that for many years it was considered necessary to compile its own statistics from special returns by members. As it is a considerable time since an alteration was asked for, and then unsuccessfully, it is particularly gratifying that the suggestion on this occasion should come

from the Department. Your Hon. Secretary had several interviews and some correspondence with Dr. Legge, which resulted in the adoption of a new and concise form of return which would show the complete results of the examination and at the same time not overload the certifying surgeon with book-keeping. The improved form of return was distributed at the end of the current year, but a number of certifying surgeons had been advised of the impending change some months before this. In order to assist members the Council has devised a simple method of keeping records which, with the minimum amount of calculation at the year's end, will provide the Department with all the information required. A large number of these record forms have been printed by the Association and bound together into various sized booklets to suit the varying annual numbers examined by those members who have adopted the system. The cost of the booklet varies, according to size, from 1s. to 4s. 6d., and members desiring replicas should communicate with Mr. Chambers.

### Joint Interview with the Chief Inspector

A letter, dated 1st March, was received from the British Medical Association conveying the information that complaints had been received respecting the inadequacy of the fees paid to certifying surgeons, and that the question had been referred to the Medical-Political Committee, which had in turn recommended the Council to co-operate with this Association with a view to getting the fees improved. Particulars were asked of the steps already taken or which it was proposed to take to this end. Details of the action taken by this Association during the past year were duly supplied, along with copies of correspondence with the Factory Department and of the two revised scales of fees issued by the Home Secretary.

It was ultimately agreed that the correct policy would be for the secretaries of both Associations to talk the matter over with the Chief Inspector of Factories. An appointment was made, and Dr. Cox, Dr. Lord, and your Hon. Secretary met the Chief Inspector and Dr. Legge, on 2nd June, at the Home Office. It was recognized by all parties, in view of the existing industrial depression, the urgent necessity for all-round economy, and the fact that the fees for certifying and examinations under special rules and regulations had recently been revised, that very special reasons must be advanced to warrant a further amendment of the minimum scales. Your Hon. Secretary pointed out, however, that the alterations made had apparently not resulted in the increased earnings anticipated by the Home Secretary when issuing his orders. This is due to the fact that the basic fee for a visit had not been taken into consideration, as had been the case when visits to the factory were first instituted, and this resulted in the actual fee paid remaining as before unless more than two patients were examined. Dr. Cox further stated that the net results showed that certifying surgeons' fees had not been increased to the same degree as those paid to other medical men employed by Government Departments. Dr. Cox further promised to supply a list of revised fees paid by other Departments, and this promise has since been carried out. Nothing further has transpired in connection with these representations since the interview.

Discussion also took place on representations made by this Association in the letter forwarded on 7th March to the effect that the compulsory provision of first aid and ambulance equipment in certain factories cannot be expected to achieve the desired results owing to the absence of further provision for medical supervision and direction. Dr. Cox was of the opinion that such a state of affairs might lead to unqualified practice and that the requisite supervision could be readily provided by a works doctor or the certifying surgeon for the district. This Association had recommended that it should be made obligatory upon the employer to obtain, every three months in the case of works employing 500 or more persons, and every six months where less than this number were employed, a certificate to the effect that the provision made was suitable and sufficient. Dr. Legge mentioned that Form 924, Part 10, strongly recommended occupiers to arrange for some form of medical supervision of first-aid boxes and ambulance rooms, and suggested that, where medical treatment was not provided, arrangements for supervision might be made with the certifying surgeon. It was pointed out, however, that dependence cannot be

placed on purely voluntary effort. The suggestion that opportunity should be taken of any fresh legislation to introduce provision for this necessary supervision was favorably received.

### Future of the Certifying Surgeon

In the report on reconstruction of the Factory Medical Service, your Council promulgated a practical and economical scheme for effective medical supervision of factories. It has always consistently maintained that the only way to deal with the appalling amount of industrial sickness and mortality is by abolishing the unhygienic conditions of occupation, that it is a Government obligation to create the necessary medical supervision in the factories themselves with a view to establishing the faults and devising the remedies, and that the certifying surgeon could be made into an extremely useful adjunct in the carrying out of a properly thought-out plan of action. Industrial preventive medicine is a branch of State medicine, and must be taken in hand by the State if it is to prove universally effective. The Factory Department's introduction of the medical element into the study of specific dangerous trades has had remarkable results in this country, but not without being followed up by statutory notifications and regulations as well as by a considerable amount of useful work by the factory surgeon. It would, therefore, appear quite logical to infer that similar machinery and methods are required to *prevent* certain well-known general diseases from singling out particular industries for their most extensive ravages and heaviest mortalities. The relief afforded by State provision of medical attendance and sanatoria diminishes the suffering but has little effect on the number of sufferers. Laboratory investigation and the medical examination of adult workers, so extensively advocated in some quarters, will not in themselves bring the goal substantially nearer.

Sad as it may seem, however, there appears to be no doubt that the Government is, for financial reasons, in no position at the present time to undertake any extension of existing obligations; and so far as concerns the certifying surgeon from the official standpoint, indications are in the direction of his remaining *in statu quo* for some time to come.

As the State is not in a position to take in hand this problem of excessive industrial mortality, it would appear to the interests of this Association to keep in touch with the efforts being made to induce employers to take action voluntarily. Whilst it is beyond doubt that only the State can reach every industry and every employer, voluntary effort within its manifest limitations has done and can do great good; even as a tentative measure it has its undoubted attractions, one of the most pronounced of which, from an employer's standpoint, is its promise of increased industrial efficiency.

The welfare movement, which is to a very large extent voluntary, has made great headway and has come to stay. The rapid rate of progress may be measured to some extent by the fact that those interested in the work have already banded themselves into two very active societies, each publishing its own journal. The Welfare Workers' Institute is the organization of those actually engaged in the work of welfare supervision, whilst the Industrial Welfare Society appears more particularly to serve the objects of employers and others interested in welfare propaganda work generally. There is also established the Institute of Industrial Administration, which includes among its activities both industrial medical matters and welfare. Another important society is the National Institute of Industrial Psychology, which is devoting certain of its energies to the study and expounding of the subject of vocational selections from the psychological standpoint, and has associated with it a number of eminent scientists.

Whilst in this country the various bodies mentioned are all, within their respective orbits, very busy in their efforts to improve the lot of the industrial worker, it must be borne in mind that America has for some time led the way in voluntary action. The industrial physician is a well-established entity in the United States; indeed, it is estimated that of thirty-nine millions of industrial workers eight millions are under the influence of medical supervision. In a considerable proportion of the works concerned the industrial physician adopts the complete plan of dealing with the problems of ill-health from the preventive as well as from

the curative side, and many establishments are thoroughly equipped with hospitals, sanatoria and research laboratories.

However little likelihood there may be of any early alteration in or extension of the statutory duties of the certifying surgeon, there is no doubt about the unofficial efforts being made to influence public opinion in the direction of medical supervision by the American method, *i.e.*, the wholesale establishment of the industrial physician, or works doctor as he is called over here. During the past year a committee of one of the organizations mentioned was understood to be holding an exhaustive inquiry into the duties, status, salary and conditions of service generally of the works medical officer, with a view to making representation to "the proper authorities" on what the position should be. Another of these bodies has held industrial medical service conferences and, it is understood, intends to hold such conferences systematically in different parts of the country; this body is also strongly advocating medical examinations at all ages.

Up to the present time the institution of the works doctor has not been advocated as a substitution for the certifying surgeon; consequently it does not require a too analytical temperament to recognize that if these appointments are made to any great extent a very objectionable overlapping must ensue. Obviously, then, the correct way to avoid overlapping is for the certifying surgeon to intimate his willingness to take on the additional duties of the works doctor whenever suitable arrangements can be made. Whole-time appointments would, of course, be outside his scope, and so would part-time appointments requiring a major portion of the surgeon's time, but as the present move is not confined to large works, but is meant to bring in the medium and smaller ones, it would appear that the certifying surgeon, who is continuously in his district, who is regularly visiting factories for statutory purposes, and who has the requisite knowledge of occupational risks, dangers, and unhygienic conditions, would be the proper person to take up the bulk of this new work. There are, of course, some certifying surgeons in important industrial districts who could not under existing circumstances spare the additional time, and these surgeons would have to consider very seriously whether, in case of necessity, it would not be the correct policy to balance matters by giving up a proper proportion of their districts. The Council is not anticipating that employers generally will show any alacrity to take up a fresh policy of this nature until a revival of trade justifies them financially, but it does hold strongly to the view that members must keep alive to the possibilities of the movement and be ready to take on any of this work when opportunity presents itself.

Attention was directed in the last Annual Report to the wisdom of co-operation with the Welfare Supervisor, and the Council is convinced that every certifying surgeon should exert himself to the utmost in this direction. The present-day importance of the certifying surgeon is not so much concerned with his absolute power to reject applicants for employment outright, as with his discretionary power to grant certificates under express conditions. This certifying of the child, or young person, for a class of employment suitable to his health and physical powers, which was strongly advocated by the old Association of Factory Medical Officers fifty years ago, was commonly, though unofficially, practised long before it became a statutory function in 1901, and the system was first expounded internationally by the Hon. Secretary of this Association at the second International Congress on Diseases of Occupations, held in Brussels in 1910. The manifest advantages which first became evident to the practical mind of the earlier certifying surgeons have latterly been very extensively paraded under the new and rather more imposing mantle of occupational orientation or vocational selection. The weakness of the system as practised in this country has always been due to the want of any provision for making certain that the conditions attached to the certificates would be carried out. Again practical experience has indicated the proper course to effect a remedy, this time by way of the Welfare Supervisor. This officer has the same relationship to the certifying surgeon as the nurse has to the practising physician or surgeon. Where the necessary co-operation has been arranged, the Welfare Supervisor sees to the proper accommodation for the examinations, takes charge of the general register, makes the required entries at

the proper time, collects the birth certificates, has the examinees ready for the surgeon on his arrival, gives any required assistance during the examinations, and, above all, makes careful note of the conditions and recommendations attached to the certificates, with the object of making certain that they are carried out. It is also an easy matter to arrange for re-examinations. This co-operation is not difficult to arrange, as it is almost universally the case that factories extensive enough, or sufficiently up to date, to have taken up welfare work, make a point of contracting with the certifying surgeon for weekly visits. Should there be found a firm which has adopted welfare without having a contract with the certifying surgeon, the latter should arrange with the supervisor for both to make representations respecting the advantages to be gained by these weekly visits; and where the converse obtains the surgeon should do his best to convert the management to the welfare movement. Co-operation is in some instances carried much further. The re-examination is extended to those between 16 and 18 years of age, and is made more complete, the employer, of course, materially increasing the contract fee. In view of the reduced number of examinations due to age limitation and other reasons, the Council strongly recommends this extended arrangement.

The action taken by the Council with respect to medical supervision of first-aid and ambulance equipment has been explained earlier in this Report. Apart from what legislation may do in the future, we know that the Department would heartily approve of voluntary arrangements being made with the certifying surgeon to undertake this duty. The Council has also every reason to believe that this supervision would be very welcome to Welfare Supervisors who are not already enjoying the exceptional privilege of working alongside a works doctor. Welfare Supervisors are well aware that first-aid in a factory is by no means confined to the preliminary dressing of wounds. All kinds of ailments are brought to their notice, and it cannot but be a distinct advantage to them, as well as to the worker and his employer, to have the benefit of medical advice in dealing with these. It should also be pointed out that the certifying surgeon can be, and has been, of very welcome assistance to Welfare Supervisors by giving addresses on some useful subject in connection with their work at the branch meetings of the Institute, which are regularly held during the winter months in various centres. The Welfare Workers' Institute publishes the excellent monthly *Welfare Work*, which might be subscribed to by every certifying surgeon with advantage. The moderate sum of five shillings annually, sent to Gloucester Mansions, Cambridge Circus, Shaftesbury Avenue, London, W.C.2, will secure regular delivery of this extremely useful periodical.

## BOOKS RECEIVED

Books received are acknowledged in this column, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

MANUEL D'HYGIÈNE. By *Dr. L. Guiraud*, Professeur d'hygiène à la faculté de médecine de l'université de Toulouse. Quatrième édition entièrement remaniée et très augmentée par Le Dr. Albert Gautié, Directeur du Bureau Municipal d'hygiène de Toulouse. Paper. Volumes I and II, pp. 1280 with preface, introduction, table of contents, and index. Paris: Masson et Cie., 120, Boulevard Saint Germain, 1922.

BIBLIOGRAPHY OF HOOKWORM DISEASE. PUBLICATION No. 11. Paper. Pp. 417 with preface, introduction, and index. New York: International Health Board of The Rockefeller Foundation, 1922.

ANIMAL PARASITES AND HUMAN DISEASE. By *Asa C. Chandler*, M.S., Ph.D., Instructor in Biology, Rice Institute, Houston, Texas. Second Edition Revised. Cloth. Pp. 572 with index, introduction, and bibliography. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1922.

HARVARD HEALTH TALKS. THE CAUSES OF HEART FAILURE. By *William Henry Robey*, Assistant Professor of Medicine in Harvard University, Visiting Physician to the Boston City Hospital. Cloth. Pp. 45. Cambridge: Harvard University Press; London: Oxford University Press, 1922.

PERSONAL HYGIENE APPLIED. By *Jesse Feiring Williams*, A.B., M.D., Associate Professor of Phyical Education, Teachers College, Columbia University. Cloth. Pp. 412 with preface and index. Philadelphia and London: W. B. Saunders Company, 1922.